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THE ECOLOGICAL FOUNDATIONS OF APPLIED ENTOMOLOGY.*

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It is my pleasing duty first to acknowledge the obligations of the economic entomologists of the country to this general society of American entomologists for giving this prominent place on its annual program to a topic which must, in the nature of the case, interest economic entomologists more than any one else. This is not by any means wholly an economic topic, however. Ecology is a very broad subject, extending in all directions far beyond the foundation lines of applied entomology; and successful ecological inquiry in the economic field, carefully verified as to results, as it must always be for practical use, may often suggest and illustrate methods equally useful in the other divisions of entomology, and hence of serious interest to every entomological specialist who does any thinking about his entomology.

It may well seem, indeed, that this general association of entomologists, inclusive of all specialists, is a higher court before which to bring our plea for a broadening and strengthening of the foundations and a widening of the relations of economic entomology, than an association composed only of economic entomologists themselves. There is no real separation in this country between economic and non-economic, between applied and unapplied, or even inapplicable, entomology. These interests are all so closely related and mutually

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so helpful that our two associations representing them are more like the right and left hands of the same body than two independent individuals. In bringing our difficult and important topic before what is virtually a union meeting of these two principal associations, we are simply bringing both hands to bear in the performance of a task which is too great for one hand alone.

Applied entomology is peculiarly an American subject, and here if anywhere in the world it should have accomplished its ends or should at least be in sight of its goal; and yet we have to acknowledge that, after generations of work upon them, many of the great long-standing problems of our American entomology are still unsolved, and that the people of our country are still suffering enormous losses of various description because of this fact. It is not because we do not know what we commonly call the *entomology* of the chinch-bug and the Hessian fly and the white-grubs and the cotton-moth that we are so nearly at our wit's end in our efforts to devise means for their control; it is because the knowledge of their entomology merely is not sufficient for the purpose. This line of attack was, in fact, thoroughly tested by the earlier economic entomologists of America. Harris, Fitch, Walsh, and the young Riley were entomological *observers* whose applications of entomology were mere inferences from their observations. The older Riley, Howard, and Slingerland, were among the first to make serious use in economic inquiry of the experimental method of scientific induction; and now we have a small army of workers applying their principles not only in precise, intensive work in the laboratory and the insectary, but on the broad scale of actual outdoor practice in varied environments, and on the long scale of season after season and year after year, postponing final conclusions until their premises stretch through a decade and extend over a continent.

It is when we search for specific reasons for our successes here and our failures there that we are driven to a scrutiny and analysis of controlling conditions of every description, and so find ourselves involved in studies so far outside entomology, commonly so-called, that we are obliged to apply for assistance to the physiologist, and the chemist, and the physicist, and the meteorologist, and the geographer, and the agriculturist, and

the animal husbandman, and the bacteriologist, and the physician, and the sanitarian, or, in a word, to the ecologist, who, from the nature of his studies, must, if he is thoroughly to cover his field, be something of each and all of these, and still something more.

The last and most essential phase in the expansion and development of our subject is the actual, practical, thoroughgoing *application* of the products of all our work. It is an important part of the main thesis of this address that applied entomology is not, in any practical and sufficient sense, entomology which is merely applicable but of which no application has ever been made; but that it is entomology actually applied to the protection, amelioration, or promotion of the welfare of man; and that, this being the scope of our topic, the means and methods of such application—the inducements, incitements, constraints, and compulsions necessary to a complete and effective application of the results of our entomological inquiries—are as much a part of our subject as any other; that they are, indeed, the most important—the all-important part, since without their successful use all that precedes must fail of its purposed end. Entomology which is not applied is not really applied entomology, any more than an ocean voyage which ends at the bottom of the sea is a completed voyage. We must get our ship into port and unload her cargo or we never shall be known as successful navigators, competent for continued command. We may find harbor pilots, and men at the docks, it is true, prepared and ready to take these terminal operations off our hands; but we must at least *find* the pilots and the dockmen, and in their absence we must discharge their functions ourselves.

This is an especially important point to us just now, for before we can discuss intelligently the foundations of applied entomology we must know how far the structure is to extend whose foundations we are about to plan. It is my insistent argument that it must, in the very nature of the case, cover the whole field of publication, education, community organization, coöperative effort, and legal compulsion necessary to give the fullest effect to the practical outcome of our entomological work; that our responsibilities, as official entomologists at any rate, do not end until we have done our best to see that all this is done or at least provided for. Just what

this signifies with respect to the ecological foundations of applied entomology we shall be in better position to see when we have come to conclusions as to the meaning of ecology itself, and as to the general relations of that subject to entomology as actually applied.

At this point I shall have to appeal to your courteous patience for permission to present a few elementary definitions, a rehearsal of which seems to me necessary to avoid possible ambiguity, uncertainty, or misunderstanding; especially so as the animal ecologists themselves are not by any means in exact accord as to the scope, description, subdivision, and nomenclature of their subject. Let us agree, then, that, for the purposes of this discussion at any rate, the subject matter of ecology may be defined as the relation of organisms to their environment, and that this means the *whole* environment, organic and inorganic, and any and *all* organisms, man included—man, indeed, as by far the most important living factor, from whatever point of view. And let us also understand that the relations meant are, first, relations of *interaction*—dynamic relations, of efficient cause, and effect produced upon the organism by its environment and upon the environment by the organism; second, *space* relations, of distribution, position, juxtaposition, and association—static relations, we may call these, since they show the status of an individual or a group at a given time with reference to the various objects of its environment; and third, *successional* relations, time relations, sometimes called genetic because, in showing the static relations of a group in successive periods, they trace the genesis of the present status.

It is evident at once that dynamic interaction with the environment is a *cause* of which static relation and successional relation are the *effects*. An organism comes to be established where it is, and associated as it is, by reason of the nature of the interactions between itself and its environment. If we imagine all exchange of action between the organism or the group and its environment to be suddenly stopped, we must see that the group would collapse, that the organism would promptly perish. If the system of interactions changes, the status changes to correspond, and not otherwise; and if these dynamic changes, however slow, are continuous over a long period and in the same direction, the changes of status resulting have the character of a succession.

Certainly, also, it is dynamic action and reaction between organisms and their environment which give ecology its main interest and importance. Status, genesis, and succession, organisms share with stones and soils and geological strata; but there is no ecology of such inanimate objects because they lack the intensity, variety, complexity, and quickness, of response to dynamic impression which organic ecology connotes. Water-spouts, clouds, flowing streams, winds, windmills, flames of fire and gasoline engines, are seats and centers of rapid action and reaction, but simple and uniform as compared with that of the living animal or plant. We may discuss their dynamic, static, and successional relations to their environment, if we choose, but we are agreed not to call these ecological. This is a term which we confine to living organisms; and it is indeed the special character of their reactions which enables us to distinguish organisms as alive.

Furthermore, there can be no doubt that it is primarily the dynamic factor only in ecology which interests the economic entomologist. It is only what insects do which gives them any importance to the economist, and it is only what can be done to them or about them in turn which gives applicable value to our knowledge of them and of their economy. We wish to know where they are or may be, how they are associated, and from whence they have come and by what they are likely to be succeeded, simply because their activities make them important to us. If they were inert we should not care.

I must further distinguish briefly between the ecology of a species or larger taxonomic group on the one hand and that of a local miscellaneous assemblage of organisms on the other. We may have an ecology of *Aphis maidiradicis*, for example, or of the family Aphididæ in general wherever they occur; and we may also have an ecology of all the inhabitants of the cornfield considered as a group of plants and animals associated in a natural habitat. From this point of view, we see applied entomology especially interested, sometimes in associational or habitat ecology, such as that of the household insects or the insects of the forest or the truck-farm or the orchard, and sometimes in species ecology or taxonomic ecology—that of a single economic insect species, for example, or that of the insect associates of a single crop plant, or the several mosquito species serving as carriers for a single disease-producing parasite.

And now what shall we say of that view of ecology by which man, with his unrivalled powers of action and influence—the center and source of the most amazing interactions ever known between an animal species and its environment—is left practically outside the natural system, or is looked upon at best as a merely monstrous overgrowth of it—a *pathological* influence, a destructive enemy of nature, all whose works are *artificial* as compared with the *natural* effects and products of the vital activities of ants and caterpillars and crawfishes. There are ecologists to whom primitive nature is the earthly paradise, and civilized man is a kind of fiend, a Satan bent upon its destruction—a triumphant Satan who seems bound to reduce the whole earth, except, perhaps, the national parks, zoological gardens, bird preserves, and the like, to conditions as unnatural, as abnormal, as those of a prison or a hospital. Their ecology is a system not of this present time but of the world before Adam, before the fall of man had introduced into the world the germs of that fatal and frightfully contagious disease known as civilization.

And there are entomologists whom any trace of humanistic values in their entomology seemingly repels almost like a taint of disease or decay. They remind one of the famous English mathematician who is reported to have said that he thanked his God every day on his bended knees that he had never discovered anything useful. This attitude is of course their privilege, as a matter of personal choice, just as it is the privilege of the ecologist to specialize in the field of uncivilized nature, or of the paleontologist to study a vanished system of life by means of its fossilized remains; but to represent these divisions of the subject as any more normal or natural or important than that phase or stage of the natural system which embraces civilized man, is not only misleading but, in my judgment, injurious. The ecological system of the existing twentieth century world must include the twentieth century man as its *dominant* species—dominant not in the sense of the plant ecologist, as simply the most abundant—for which idea *prevalent* would, I think, be a better term—but dominant in the sense of dynamic ecology, as the most influential, the controlling or *dominant* member of his associate group.

In applied entomology this is all of course very obvious, and needs no elaboration; for the economic entomologist is an ecologist pure and simple, whether he calls himself so or not—a student primarily of the interactions of insects and men, of that part of the actions and ecology of insects by which the welfare of man is affected, of that part of the ecology of insects which overlaps upon the ecology of man and that part of the ecology of man which overlaps, or can be profitably made to overlap, upon the ecology of insects. And it is the human interest which predominates and controls; the motive to applied entomology is primarily humanitarian. If there were no human interest to which entomology is applicable, there would be no applied entomology.

Now, since the field of applied entomology is precisely and solely that part of ecology in general over which the ecology of man and that of insects is coincident; since it is simply the ecological area common to two classes which differ almost immeasurably in their endowments, general interests, and natural relations, it must be evident, *a priori*, that a knowledge of the broad field of ecology as a whole, and of its general aims, principles, processes, and products, is fundamental to the special studies of the economic entomologist. It is only in some such sense as this that we can properly speak of the "ecological foundations of applied entomology" at all. The very substance of applied entomology being ecological through and through, it can have a foundation in ecology only as a part is founded upon the whole, as an apex is founded upon a base, as special aspects and applications of a subject are based upon its general principles and its most comprehensive characters. It is my special task, therefore, to point out and illustrate some of the ways in which general ecology may be made helpful to applied entomological ecology, and, *vice versa*, ways in which applied entomology may be made useful—is already useful, indeed—to the student of general ecology.

A distinguished dean and professor of agriculture in one of our leading universities told me quite lately that the great need of practical agriculture at the present time is nothing less than a scientific study of vegetable physiology—the physiology of the common crop plants—concerning which we know so little that is exact and exhaustive that even the so-called scientific

farmer is still practicing his art in great measure as did his remote predecessors, by rule of thumb. He paid us the compliment of saying that the economic entomologists of the country are much farther advanced in this respect than the agronomists—that we know more of the corn insects than the corn breeder knows of the corn plant. I did not tell him, as I might have done, that this opinion simply signified that he knew less of entomologists and the state of their knowledge than he did of corn and the corn farmer; for this is also our case. How many of our measures of protection and defense against insect depredations depend upon any precise knowledge of general fact or scientific principle, or are traceable to anything better than a purely empirical warrant? If we attempt to analyze what we know and what we still need to know concerning any one of the great insect pests before we shall be in a position to do all that can be done and ought to be done to restrain its ravages and injuries either by measures of avoidance, prevention, mitigation, or arrest, we may perhaps get a clearer, concrete idea of what is involved in economic entomology, and what are the foundations of fact and principle upon which it rests.

The chinch-bug of our western grain fields has been a subject of close, though inexpert, observation for nearly a century, and of much expert study and experiment for more than a generation; but during this present year, in my own state, where we have used against it every method and device which we could induce those most immediately concerned to apply, millions of dollars worth of farm crops have been destroyed by it, and a large part of the rural population of whole counties has been brought close to economic distress and in some cases to financial ruin.

We know the facts concerning the geographical distribution of this insect species, without which, of course, we should not know where to expect its ravages and to provide against them, but this is for us a matter of observation merely, and not of scientific inference or rational interpretation; we do not definitely know what are the *limiting conditions* of its distribution in any direction. Over parts of its occupied area it is present only in numbers economically insignificant, and we have little actual knowledge *why* it is destructive in a part of its territory

and not elsewhere. Still less do we know just why the boundaries of its area of destruction fluctuate in its various outbreaks, or why the foci of its injuries shift from place to place in successive years.

We know that such an outbreak or uprising is commonly preceded by widespread drouth for two or more years, and that as a rule its disappearance follows upon a season or more of comparatively wet weather, especially at its hatching time; but we do not know enough of other agencies contributing to either movement to give us means of either explanation or prevision; and of the climatic or meteorological agencies which seem to produce these effects, we do not know how or why they produce them, whether by some direct action upon the physiological or reproductive processes of the insects themselves, or indirectly through effects produced upon the food plants of the species, or upon its disease germs, or upon its newly discovered egg parasite, or upon several or all of these at once, together with other agencies as yet unknown.

Concerning its single known effective insect parasite, discovered only last year, a species which seems to have specialized upon the chinch-bug's egg, we know that its rate of multiplication so far surpasses that of its host that under favorable conditions it may rapidly overtake the latter and reduce an outbreak to insignificance—an apparently available weapon of first-class importance which has been made ready to our hands; but just what *are* the conditions favorable to its appearance, spread, and rapid increase, and whether these processes can be hastened artificially or not, of this we know nothing. We do not even know concerning this or any other parasitic insect how the parasite and the host are brought together in the field, whether because they have been so similarly tuned and timed to their environment that they find themselves brought into each other's neighborhood automatically, because of like reactions to their surroundings, or by some more occult and less certain process.

We know that at the beginning of a chinch-bug outbreak fungous disease seems to have little or no effect upon the rapidly multiplying hordes, but that when it is declining they sometimes burst forth like a flame in dry fuel. We have strongly suspected that this is due to a diminished average

vitality in the victims, but we can only guess at possible causes of decrease in their powers of resistance; and of these disease-producing fungi we know too little, either of their effects, of the comparative virulence of the various species, of variations in the virulence of different strains of the same species, or of the possibility of increasing their effect by selective cultures of the most virulent varieties.

We know that the chinch-bug is strictly limited for food to plants belonging to the grass and sedge families, but we do not know why it can not feed—refuses even to try to feed—upon other plants, although prompt starvation is the alternative; nor do we know why it plainly prefers some of its natural food-plants to others, and why it thrives best and multiplies most rapidly upon those which it prefers. We do not even know by what tests or senses it distinguishes its favorite foods or avoids those upon which it can not live.

We have noticed, where this insect sweeps in hordes across a field, infesting all plants substantially alike, that here and there one may stand alive and erect while all its companions have perished; but we do not know why this should be so or whether by a selection of such escaping victims we might breed repellant or resistant lines, increasingly capable of withstanding attacks destructive to the average of their kind.

We know the ordinary life history of the chinch-bug fairly well, although our knowledge is still lacking in the details of variation of life history in different regions, seasons, and climates; while of its so-called physiological life history we know almost nothing exact.

We know that an invaluable opportunity is afforded us at harvest time to destroy the pest as it attempts to escape on foot from the dry wheat stubble. We know that a line of crude creosote poured upon the ground is practically impassible by it, and that this simple fact of ordinary observation may be utilized to arrest its dispersal and, by the addition of post-hole traps along the line, to capture and destroy it by bushels and barrels and even by wagon-loads; but we do not know what it is in the creosote line which makes it seemingly impassible, since occasionally, or under extraordinary compulsion, the insects cross it without the slightest injury. Consequently, in our search for more desirable substances for this use we have

to pick and choose at random, being quite without the guidance of any general knowledge of the physiological sensibilities of the species.

We know that certain insecticide substances in solution or emulsion are effective against it in a way to make them practically available, but we do not know how or by what properties they produce their fatal effects and we are consequently without definite guidance in our search for other such insecticides.

We know that any and all measures against this insect are of comparatively little avail if undertaken sporadically, by an individual only here and there; that for their fair and full effect they must be made the fixed policy and practice of whole communities, actuated by the community motive as well as the personal one. We know indeed that a large part of our applied entomology fails of its application because communities are not brought to the point of coöperative action in the general interest; but we do not know—we have scarcely discussed among ourselves—the best means of appeal and the best methods of organization and management to effect these results, without which much of our economic entomology must fall practically short of the economic end.

We realize that the actual utility of all our work depends upon a general knowledge of its practical product, and of possible methods of its utilization in every case arising, and on an exercise of a sound judgment in the adaptation of such methods to the conditions of the time and place; but we are far from any kind of satisfying success in making such knowledge the common property of the people most concerned and in training and assisting the common judgment to make the best use of the knowledge they possess.

We well know that no people can be brought to do spontaneously all that they ought to do in our field in the common interest, and that education, persuasion, encouragement, incitement, and organization even, must be supplemented by legal requirement and by law enforcement if the people are not to suffer clearly avoidable losses of property, comfort, health, and life itself, due directly to insect infestation, and we have made considerable progress of recent years in securing legislation, state and national, in some parts of this field; but it still

remains true that the land owner who may be sued for damages if he permits his horse to break into his neighbor's garden is not even liable to reproof if he raises caterpillars in armies, Hessian flies in swarms, and hordes of chinch-bugs, to destroy his own crops and then to spread throughout his neighborhood as a general menace and calamity.

And so I might go on to enlarge my list of things done and things remaining to be done in various other lines of effort and activity if we are to do all that is needed to make our entomology applicable, and to secure the application of it. But I have gone far enough to illustrate the fact that the useful things we know and those we still need to learn are practically all items in the physiology and ecology of our injurious species, and that the physiological items are of practical interest to us solely because of their ecological significance. Even the human factors of our economic problem are really ecological, for they have to do with the relations and interactions of men among themselves, as affected by the relations and interactions between themselves and their insect enemies.

If you ask me now whether we should be any nearer the practical control of our most dangerous and destructive insect pests if we had the details of their ecology well worked out, I shall have to answer that I do not know, any more than the entomologists who studied the habits and general ecology of mosquitoes foresaw the use of their observations as an indispensable link in the study and control of malarial disease—any more than Laveran knew when he found a blood parasite associated with malarial disease in man that the remaining links in the chain would presently be traced.

We can have, in fact, no better illustration of the economic value of ecology than this subject of insect-borne disease, the one of its kind which by the joint labors of entomologists, parasitologists, physicians, legislators, and administrators has been brought to the point of a scientific and practical success, perhaps the most remarkable and the most nearly complete of any achievement of applied entomology. Let us make of this a sample and test of successful research, distinguishing the successive stages in the discovery of the nature of malarial disease and the modes and means of its propagation—the joint conquest, as Sir Ronald Ross remarks, of medicine and zoology fighting side by side.

There was, to begin with, a general background of knowledge, variously acquired, of the parasitic relationship—the relation of internal parasite and animal host—a purely ecological subject. Next in logical succession came the question of the paths and modes of transmission by which a parasite passes from host to host—again an ecological inquiry, in the course of which it was found that some parasites require two kinds of hosts in alternation for the completion of their life histories, and that these two hosts are usually—almost necessarily, indeed—animals ecologically associated. In rational but not chronological order, then follow (2) the discovery of *protozoan* parasites, eventually including a blood parasite in man invariably associated with malarial disease, and a special study of the habits and development of this parasite in man; (3) prolonged but vain search for it outside the human body in situations where malarial disease was prevalent; (4) the suggestion of mosquitoes as possible carriers of the malarial poison, a hypothesis based on the coincident distribution of mosquitoes and malaria; (5) experimental tests of this hypothesis by the feeding of mosquitoes with blood from malarial patients, and search for the human-blood parasite in their bodies—experiments which were successful when the right species of mosquito were chosen; (6) studies of the life history of the parasite in the mosquito's body; (7) successful experiments in the inoculation of man with malarial disease by means of mosquitoes containing the malarial parasite; (8) field studies of the precise distribution and reproductive habits of Anopheles; (9) experiments with practical measures for the local control of malarial disease by an elimination of the breeding places of malarial mosquitoes; (10) the construction of a program of practical operation and requirement for the local abolition of malaria; (11) the passing of ordinances and the issuing of orders for the execution of this program; and finally (12) the organization and management of a competent executive force, with authority sufficient to carry such a program out effectively. Thus was accomplished the virtually perfect result in Panama; and by a duplication of these methods, so far as they were applicable to a disease whose germ has never yet been seen, yellow fever was also mastered.

In all this series it is the *last* step which costs; the malarial parasite and the mosquito are less refractory to the control of man than man himself; it is less difficult to perfect methods for

preserving life and health than it is to induce the threatened victims to make use of them effectively. So true is this, even with respect to malaria, that Sir Ronald Ross has said, in an address delivered in London a month ago, that although fifteen years have elapsed since the essential discoveries were made, not more than a tenth part of the possible benefit to human life has been effected, and that this is only because mankind has not put its heart effectively into the business. In the purely economic field also this is equally true, and in my own state further progress in the control of the chinch-bug and the corn root-aphis seems to be blocked, as by an impassible stone wall, by the disinclination of the people most immediately concerned either to do voluntarily or to permit themselves to be coerced into doing the necessary right thing in their emergency. They would rather do as they like to their ruin than to be commanded, and perhaps compelled, to do as they ought for the salvation of themselves and their communities.

Both of my foregoing illustrations, one of a complete and the other of an incomplete investigation, show us how thoroughly ecological applied entomology is in its distinguishing characters; but they do not sufficiently distinguish specific ecological detail from general method and principle, or give us any convincing evidence of the advantages which applied entomology may hope for in the work of the general ecologist who seeks only to develop his subject in the broad way, with no special thought of useful applications.

For this we need only to recall what it is that the general ecologist undertakes to do. For us as students of applicable entomology and of the means and methods of its application, the question is, in general terms, whether it would help us in our special work if we knew in advance, or could readily learn, the essential facts concerning the environment of the animals or plants in which we are especially interested; if we knew the topography of the environment, its hydrography, and its climate, as these are now and as they were before civilized occupancy; if we knew about the water supply, the drainage, the past and the present levels of the water table, the soils and their distribution, and the effects upon these of occupancy and use, present, past, and prospective; if we knew the details of the ecological structure of the region, and the probability of changes in such structure under gradually intensified human use; and

if, among many other particulars the mere enumeration of which would quite exhaust your patience, we knew the facts concerning the temperature, light, and moisture of the air in different situations at different levels and during all seasons of the year.

None of this matter is entomology, but it, and very much more of the kind, is entomological ecology, because it is an indispensable part of a description of the ecological environment of insects—of that part of the physical environment which enters into relations of cause and effect with the insect species which it environs.

Would it not further help us greatly if we knew, or could readily learn in advance, even the more general facts concerning the reactions of insects and groups of insects, especially the economic species, to these various factors of their environment, as worked out under precise experiments verified by observations in the field—their reactions in their several generations and in the various stages of their life history—and the effects upon their welfare of natural variations in these several environmental factors; if we knew also much more than now of the general relations of insects to the other organisms of their neighborhood, especially to those upon which they feed, and of the relations of *these* organisms and their products to the several factors of the physical environment?

To me it seems so evident that such a knowledge would be of the greatest value to the investigating economic entomologist, that I am quite prepared to paraphrase the statement of Dean Davenport concerning the agricultural need of vegetable physiology by saying that the greatest need of applied entomology at the present time is just this kind of scientific ecology, and that it is among our first and most important duties to acquaint ourselves with this field and to encourage, provide for if possible, and assist as we can, serious, exact, and thoroughgoing work in scientific entomological ecology.

It is now time, indeed, for me to say that entomologists in general are not lacking in an appreciation of these facts or in a cultivation of these interests; that, without waiting for the ecologists to bring grists to their mill, they have gone out into the fields and have harvested and threshed much grain for themselves; that they have of recent years done considerably more, I think, in entomological ecology than has been done by

the professed ecologists, and that they are quite disposed to meet the latter gentlemen a very liberal halfway in the exploration and exploiting of their common territory. It is something of an obstacle, to be sure, to a coöperative understanding of these two groups that they look in opposite directions, and thus approach each other backwards, the economic entomologists being interested primarily in conditions as they are and may be made to become, referring to the past only for clues useful in the solution of problems of the present and the future, while the pure ecologists are looking rather to the reconstruction of a vanished or vanishing past, and tracing ecological history as far back as their data will permit. Each of these two groups is performing, indeed, its most essential function; but it will certainly be to the advantage of both that they should understand each other and should make the cross-connections necessary to enable each to apply the other's products and to avail itself of the other's services.

It will help us perhaps to a clearer idea of just what kind of ecology is most needed in applied entomology if we see what, in general, the economic entomologists have lately been doing in the ecological field. A survey of reports and papers which have appeared in quite recent years will show us that, in addition to the kinds of ecological data which have now become standard in discussions of economic species, there is a considerable quantity of most interesting new work being done by entomologists on the effect of variations in temperature and moisture upon the metabolism, reproduction, and life history of insects—virtually an attempt to isolate the elements of weather and climate and to experiment with them separately as preliminary to experiment with the various combinations of them present in nature. These are the first steps in a very long road, with branches running in many directions.

Pursuing one of these branches a few years ago I found myself on the boundary line of vegetable physiology, where I was fortunate enough to meet a botanical ecologist willing to go my way, and to him I was permitted to turn over the inquiry I was making, with a result, lately published in a doctor's dissertation at the University of Illinois, that the reason why I was sometimes driving injurious insects away from corn hills, with no injury to the seed or plants, by a preliminary treatment of the seed with repellant oils, but sometimes, on the other

hand, was injuring or killing the corn, was because the permeability of the coats of the embryo of the corn plant to oils varies with the amount of moisture in the kernel, the wet corn kernel absorbing these oils quickly to the injury of the plant, while the relatively dry kernel absorbs them slowly, with no injurious consequences. My discrepant results were thus due to mere differences of weather at planting time in the several cases.

The kind of ecology which entomologists, intent on the solution of their special problems, are *not* now undertaking—are scarcely in a position to undertake—is the formulation and elaboration of general principles—the laying of foundations broad and deep. For their emergency structures, they are digging down a little way as well as they can, or are merely building, perhaps, on the bare ground. But this is because the ecologists have not yet built—are only beginning to try to build—foundation structures up to their level. When the ecological foundations are well and truly laid, then our entomological superstructures will rest upon them, as a matter of course.

Associational ecology, a favorite subject with the pure ecologists, is another division to which entomologists have thus far given little attention—too little, I think, for their own good. Even where we treat in a comprehensive way of all the insects infesting a single crop plant—deal, that is, with a mixed association in which the crop plant is the prevailing, central species—we pay little attention, as a rule, to the ways in which the different insect members of the group interact with each other, unless, indeed, they are parasitic or predaceous.

Pardon me if I draw once more upon my own experience for a simple illustration of the relations which may be made out by a comparison of the data of associated species. It was in a study, made more than thirty years ago, of the insect population of a strawberry plantation that I noticed the curious way in which three species of coleopterous larvæ succeed one another in their injuries to the roots of the strawberry plant, the life histories of the three being so adjusted, as by a kind of dovetailing process, that simultaneous competition is completely avoided, each species appropriating its share of the growing rootage of the plant in its turn, and all thus drawing from it a much larger food supply than if their drafts had been coincident. This fact was the more striking when it was seen that

one of these so-called root-worms differs so widely in its life history from another species of the same genus, living in the same territory but upon another food plant, as to suggest an actual fitting of it in, by a process of natural selection, to the period left vacant for it by its two companion root-worms of the strawberry field.

Ecological succession has also its points of contact with economic entomology, as is being shown at this very meeting of the Association of Economic Entomologists, in a paper by one of our leading zoological ecologists.

If, now, I may apply my own description of ecology, as inclusive not only of all kinds and grades of interaction between men and insects but also of all interactions among men which have insect activities as their cause, I may conclude this outline of my subject by brief reference to the things which our countrymen ought to be induced to do in each other's interest as well as in their own. The great obstacle to a reasonable success is, as I have already intimated, a deficiency of the community spirit in the American community. If our people had, as a mass, a fair equivalent for the disposition to social cooperation, to social service, to social sacrifice when sacrifice is needed, that is exhibited by some of their insect competitors, our conquest of the insect world would be relatively easy. In that case, whenever a community was threatened with a destructive insect outbreak, it would react unanimously, effectively, and at once to the warnings of its posted sentinels—its official economic entomologists. Knowing itself to be without the inherited automatic machinery of coöperative action which makes a hive of bees or a colony of ants a unit when its welfare is threatened, it would provide itself in advance with artificial substitutes for this constitutional system. It would equip itself and its progeny with the necessary practical knowledge, it would cultivate by all possible means the necessary public spirit, and then it would surround itself with laws and ordinances and provide itself with officers, to the end that it might be constrained to do, even against the will of many of its individuals, what under like circumstances a family of social wasps would do because it could not help itself. Taking a lesson, in other words, from insect ecology, it would contrive to do by the aid of rational intelligence, forethought, and will

at least as much for the common welfare as the insect does in the interest of its kind under the impulse of a wholly ignorant instinct.

I venture now to hope that I may have made by this time a sufficient showing of the fundamental nature of the connection between ecology and applied entomology to justify a few closing sentences upon the educational bearings of my conclusions. If applied entomology is essentially a mixture of human and insect ecology, then it seems clear that courses in general ecology should form a part of the education of the economic entomologist. Indeed, I have much tangible evidence of the value of this combination in the results shown in my own university department of entomology, whose more capable students all tell me of the unique advantage which they find in ecological courses because of the broader outlook and the new point of view which these give them, and especially because of the greater theoretical interest of their technical studies when related to the foundation principles of ecology. The ecological environment is a complex of causal agencies, without an analysis and interpretation of which an adequate knowledge of causes in biology is impossible.

I believe that students of ecology itself would be equally, although somewhat differently, profited if they were to take one or more economic courses in entomology; that they too would find a new outlook thrown open to them and a new and larger meaning given to their work. I hope that the time may soon come when ecology shall be taught in at least every state university and every agricultural college, and when something of applied biology shall be included among the regular courses of every university student specializing in ecology. Then for the first time we may be in a position to estimate fairly the value of the contributions which entomological ecology, fully and thoroughly applied, may be competent to make to the progress of biology and to the welfare of civilized man.

Urbana, Illinois, December, 1914.

MORPHOLOGICAL STUDIES ON THE HEAD AND MOUTH-PARTS OF THE THYSANOPTERA.*

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INTRODUCTION.

The small insects of the order Thysanoptera have four long, narrow, membranous, flat, fringed wings. Only a few veins are present in the wings and when at rest they are laid horizontally along the back. The sucking mouth-parts form a cone at the caudo-ventral margin of the head-capsule. The maxillae, in part, and the left mandible are modified into piercing organs and enclosed within the mouth-cone. The mandibles, clypeus and maxillary sclerites are asymmetrical. The tarsi are two-jointed, bladder-like at the distal end and without claws. The metamorphosis is incomplete.

The order is divided into two suborders, Terebrantia and Tubulifera. The more important distinguishing characters of these are as follows: The female of the Terebrantia has a saw-like ovipositor. This is wanting in the female of the Tubulifera. In the Terebrantia the terminal segment of the abdomen of the female is conical, while that of the male is rounded. In the Tubulifera the distal segment of the abdomen is tubular in both sexes. One or more longitudinal veins

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extend from the proximal to the distal end of the wings in the Terebrantia, while only one, partially developed, median vein occurs in the Tubulifera.

The Terebrantia are divided into two families, Aeolothripidae and Thripidae, while only one family, Phloeothripidae, occurs in the Tubulifera. It is generally stated by investigators in this field that the Terebrantia are the more generalized and of the two families in this suborder the Aeolothripidae are the more primitive. The following brief summary of the evidence as discussed by Uzel in his "Monographie der Ordnung Thysanoptera," page 22, supports the above statement.

The wing characters of the Terebrantia are more generalized than those of the Tubulifera. The wings of the Terebrantia possess one or more complete longitudinal veins and in some cases cross veins, while the Tubulifera have only one partially developed longitudinal vein and no cross veins. Cross veins among the Terebrantia are present only in the family Aeolothripidae. The antennae of most Aeolothripidae are nine-segmented while in all other thrips except the genus Heterothrips there are six to eight segments found. The maxillary palpi of the Aeolothripidae are four-segmented, while those of the Thripidae are usually three-segmented and those of the Phloeothripidae are composed of two long segments. The labial palpi of the Aeolothripidae are always four-segmented while those of other thrips have but two segments. The above data permit the assumption that the Terebrantia are more primitive than the Tubulifera. This assumption is substantiated by the comparative studies of the suborders made in this paper.

The primary purpose of this research is to reach as definite a conclusion as possible in respect to the interpretation of the asymmetrical mouth-parts of the Thysanoptera. The literature of this subject shows a decided diversity of views as to their homology and function. Some investigators consider the mouth-parts as fitted for biting, and others as fitted for sucking. The more recent workers, while agreeing that they are of a sucking type, yet disagree as to the homology of the mouth-parts. Besides the study of the mouth-parts, many interesting head structures have been observed. Of these the pharynx, salivary glands and head-glands are discussed and figured.

In view of the limited nature of the morphological studies of former workers, specimens of as many species of thrips as possible were secured for this work in order that an extensive view of the conditions in the order might be observed. Twelve or more species were used and of these the following nine were identified: (1) Heliothrips femoralis Reuter, (2) Frankliniella tritici Fitch, (3) Thrips physapus Linne, (4) Cephalothrips yuccæ Hinds, (5) Haplothrips verbasci Osborn, (6) Thrips tabaci Lindeman, (7) Chirothrips manicatus Haliday, (8) Anaphothrips striatus Osborn, (9) Limothrips cerealium Haliday.

The first five species in the above list are very abundant in the vicinity of Urbana and as living material was necessary for certain methods of preparation used, the most of my observations were made on these. Fortunately these have proven to be typical and also comparatively easy to dissect and section. Heliothrips femoralis was present thruout the year in its nymphal and adult stages in the city and university greenhouses. Cephalothrips yuccæ was found thruout the year between the closely appressed leaves of the crown of the yucca plant, Yucca filamentosa. Its nymphal stages are abundant from April to December. Only the adult stages of the following were found: Frankliniella tritici occurs in great numbers in the flowers of peonies, roses, composites, etc. Thrips physapus was very abundant in the flowers of dandelions and Haplothrips verbasci can be secured the year around on mullein. Of the above five genera, Heliothrips, Frankliniella and Thrips belong to the suborder Terebrantia while Cephalothrips and Haplothrips belong to the suborder Tubulifera. The nymphs of Heliothrips and Cephalothrips and the adults of all five species mentioned have received similar treatment and observation.

Thruout the following discussions the structures as they exist in the generalized Terebrantia are considered first and the Tubulifera are compared with them. The generic names have been used in the different discussions and on the figures since only a single species of each genus has been considered. The term nymph is used in the following pages to designate the feeding, active, immature stages. In most cases only the older nymphs were used, however, a few observations were made on the early instars, but these did not differ from the

later instars. The term semi-pupa is used in this paper for the semi-quiescent instar just before the adult stage and it is only referred to in the suborder Tubulifera.

METHODS.

For general purposes thrips should be killed in boiling water and preserved in 70 per cent. alcohol. When only the chitinized parts are desired, living or preserved specimens should be boiled for ten or fifteen minutes in a 10 per cent. solution of potassium hydroxide, then reboiled in water to remove the alkali, and finally preserved in 70 per cent. alcohol. Living material treated in the above manner is better than preserved material, for preservation in alcohol tends to make the specimens too brittle for careful dissection.

The use of a Leitz binocular microscope made possible the dissection of the minute mouth-parts. A number of media were tried in which to make dissections; carbol-aniline oil proved to be the best. Its good qualities are that it evaporates slowly and will clear specimens from any grade of alcohol above 50 per cent. If it be desirable to stain with safranin or orange G the stain can be dissolved in 95 per cent. alcohol and will readily mix with the carbol-aniline oil.

The staining of the material for dissection with safranin proved to be very useful in differentiating the almost colorless mouth-parts of some of the species. In using aniline oil in any form one precaution must be observed; as much as possible of the oil should be removed with a blotting paper or a dry rag or by replacing the carbol-aniline oil with carbol-xylene or xylene before mounting in balsam. If the oil be not removed the media in which the parts are immersed will eventually darken.

Material for sections was fixed with hot (80° C.) corrosive sublimate (saturated corrosive sublimate in 35% alcohol plus 2% of glacial acetic acid) for 15 to 30 minutes, which was replaced by 70% alcohol containing a few drops of iodine for 24 or more hours.

Paraffin having a melting point of 52-54 C. gave a sufficiently firm medium in which to cut sections as thin as five microns. Erhlich's and Delafield's haematoxylins were used for staining sections on slides and orange G. or safranin for counter-staining. The best results were obtained by staining punctured specimens in toto for 24 hours in Delafield's haematoxylin or from 3 to 7 days in borax carmine.

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This investigation was carried on under the supervision of Dr. A. D. MacGillivray and Dr. J. W. Folsom, and to these men I am greatly indebted for the sincere interest shown and the many valuable suggestions received. For the use of the data on the tentorial structures and their relations in insects in general referred to in this paper, I wish to express my thanks to Dr. A. D. MacGillivray, who allowed me the free use of his unpublished manuscript; and to Miss Margaret Washington for the loan of drawings of the tentorium. I am indebted to Mr. J. D. Hood, of the U. S. Biological Survey, for the identification of the following five species: Heliothrips femoralis Reuter, Frankliniella tritici Fitch, Thrips physapus Linn., Cephalothrips yuccæ Hinds, and Haplothrips verbasci Osborn; to Dr. A. F. Shull, of the University of Michigan, who kindly furnished several species of named thrips; Euthrips (=Frankliniella) tritici Fitch, Thrips tabaci Lindeman, Chirothrips manicatus Haliday and Anaphothrips striatus Osborn; to Professor H. Garman, who supplied me with a few specimens of Limothrips cerealium, the species he used in making his observations; to Dr. W. E. Hinds for identifications and information, and to Professor S. A. Forbes and Dr. J. S. Kingsley for corrections and suggestions.

FIXED PARTS OF THE HEAD.

In the order Thysanoptera the gross arrangement of the head and mouth-parts (fig. 1, 2, 5, 8, and 11.) is homologous with the corresponding arrangement of the head and mouth-parts of a generalized homopteron. The cone-like mouth-parts are attached to the caudo-ventral portion of the head-capsule and project caudad between the prothoracic legs, and the antennae are located at the extreme cephalic margin of the head between the compound eyes (fig. 1 and 8).

HEAD-CAPSULE (fig. 1, 2, 5, 7, 8, 9, and 11).—Head structures in thrips differ in many respects from those of a generalized insect. In the head-capsule nearly all of the sclerites are completely united and all traces of sutures have been lost. On account of this union the following areas of the head, front (fr.), vertex (vt.), genae (g.), and occiput (o.), are designated only in a general way on the figures. The labrum and the

asymmetrical clypeus are the mesal pieces on the ventral aspect of the mouth-cone. The compound eyes are located at the latero-cephalic corners of the head-capsule, and the ocelli when present are between the compound eyes on the dorsal aspect of the head.

Heliothrips femoralis (fig. 1, 2, 5, 7, 12, 13, and 19).—A line extending between the vertex and the mouth-cone on the head of a nymph of Heliothrips has a dorso-ventral position, while a similar line on the head of an adult has a cephalo-caudal direction. The position of this line or axis in the nymph suggests a similarity to the position of the head of an orthopteron (Acrididae), while the position of the head of the adult is similar to the position of the head of an homopteron (Cicada).

The head-capsule of the nymph is non-reticulated and slightly chitinized, while that of the adult is highly reticulated and heavily chitinized. The mouth-cone of the nymph occupies more than one-half of the cephalic aspect of the head-capsule and extends ventro-cephalad, while in the adult it is comparatively smaller and projects ventro-caudad.

Two similar caudal projections (c. a.) arise from the ventro-caudal margin of the head-capsule of the nymph and extend for a short distance as narrow pieces between the maxillary sclerites (mx. s.) and the submentum (sm.). In the adult of Heliothrips the caudal projections (c. a.) differ from those of the nymph in that they are decidedly asymmetrical. The left projection is broadly joined to the head-capsule while the broad right projection has a narrow, neck-like attachment. This striking asymmetry is possibly due to the excessive lateral extension of the clypeus toward the right side. The asymmetry of the caudal projections of other adult Terebrantia such as Thrips physapus Linne (fig. 3 and 6) is not as prominent as that found in Heliothrips. The caudal projections articulate along their dorsal sides against certain sclerites of the prothorax.

The asymmetry of the head-capsule of the nymph and adult is very evident in a frontal view (fig. 1 and 13). About half-way between the meson and the left side of the head-capsule on the ventral margin of the front there is a decided recurrent angle which is very distinct in the adult. The thickenings, depressions, and invaginations on the frontal area of the head will be discussed under the internal head-skeleton.

Cephalothrips yuccæ (fig. 8, 9, 11, 17, 18, and 20).—A line extending between the vertex and the mouth-cone on the head of a nymph or adult of Cephalothrips has a cephalo-caudal position and thus in all its stages the position of the head-capsule resembles the position of the head of an homopteron (Cicada.). The nymph of Cephalothrips is very different from the nymph of Heliothrips.

The head-capsule of the nymph and adult is smooth and non-reticulated. The mouth-cone of the nymph occupies about one-half the ventral aspect of the head (fig. 17), while in the adult it is reduced to about one-third the ventral aspect of the head (fig. 8). This reduction is clearly shown in the semi-pupal stage (fig. 20). The dotted line across the head indicates approximately the point of attachment of the mouth-cone as it would be in an active nymph. This line is distinguishable in the early stages of the semi-pupa by a difference in the staining quality of the two areas on the ventral aspect of the head. With the reduction of the mouth-cone of the Tubulifera, striking modifications have resulted in the form of the clypeus, the left maxillary sclerite, and the piercing organs. The modification and the reduction of these parts during metamorphosis are of great value in determining their homology.

Symmetrical, caudal projections (c. a.) are present at the ventro-lateral margins of the head-capsule of the nymph and adult. The caudal projections of the adult are prominent and terminate in distinct acetabula which fit against certain sclerites of the prothorax (p. s.). This arrangement permits of a dorso-ventral movement of the head.

The asymmetry of the caudal margin of the front of the adult is not prominent and in the nymph no asymmetry can be seen. The recurrent angle in the adult is located in a position similar to that in Heliothrips.

An unidentified suture (s.) occurs on the lateral aspect of the head-capsule of the adult dorsad of the caudal projections. There is also an indication of a suture along the dorso-caudal margin of the head. This suture along with the thickenings and invaginations on the frontal and genal areas of the head will be considered later with the discussion of the internal head-skeleton.

CLYPEUS AND LABRUM.—The clypeus and labrum are the mesal pieces on the ventral aspect of the mouth-cone.

Heliothrips femoralis (fig. 1 and 13).—The adult and nymph show no marked differences in the form of the clypeus and labrum. The clypeus (cl.) is the large asymmetrical piece, and the convex piece at its distal end is the labrum (lr.). Garman and other workers have considered the area cephalad of the line f as the clypeus and the area ventrad of this line as the labrum. With this interpretation one meets with considerable difficulty in homologizing the parts in the two suborders. If the line f is a suture, it can not be the clypeo-labral suture, but must be the proximal margin of the clypeus. The area between this so-called suture and the front is a broad hyaline membrane (me.). In safranin-stained material, it is slightly colored while in sagittal sections stained in haematoxylin it shows a decided blue tinge. The above interpretation of the line f may be correct, but a better interpretation seems to be that it marks the point where the heavily chitinized, proximal end of the clypeus becomes more or less membranous, and thus permits the dorsal and lateral movements of the mouth-cone. The line f is located in a deep fold from which point the mouth-cone extends in a caudo-ventral direction in the adult and cephalo-ventrad in the nymph. A distinct line or suture (s.) can be seen extending from the recurrent angle on the front to the left lateral end of the line f. This suture is the left lateral margin of the clypeus and shows distinctly in the nymph of Heliothrips (fig. 13) and in the adult of Thrips physapus (fig. 3). This evidence supports the interpretation that the entire area from the front to the small convex labrum is the clypeus. Garman's drawing of Limothrips cerealium shows clearly the above clypeal and labral areas even tho he interprets the parts differently.

The clypeus (cl.) is an asymmetrical triangle with its right latero-cephalic angle decidedly more cephalad than its left latero-cephalic angle. The left margin of the clypeus is a comparatively straight line from the front to the labrum and nearly parallel with the meson, while the right margin in the adult is a curved line and extends at a decided angle to the meson from the labrum to the point of attachment of the right caudal projection with the head-capsule. This unique asymmetry is characteristic of all the Terebrantia examined.

Cephalothrips yuccæ (fig. 8 and 17).—In the nymph of Cephalothrips the clypeus (cl.) is a long, V-shaped, nearly symmetrical piece attached to the caudal margin of the front (fr.). The fronto-clypeal suture between the clypeus and the head-capsule is wanting. The small, distinct, convex piece at the distal end of the clypeus is the labrum (lr.). The clypeus of the semi-pupal stage is smaller than that of the nymph on account of the reduction of the mouth-cone. It is symmetrical and shows a distinct fronto-clypeal suture, but the clypeo-labral suture is not present, however, it is indicated by indentations on the lateral margins of the clypeus near the distal end of the mouth-cone. The ventral margin of the labrum is bilobed indicating its future adult structure. Within the semi-pupal parts the developing adult structures can be seen.

In the adult (fig. 8) the clypeus and labrum have been modified thru the reduction of the mouth-cone, but they are distinctly differentiated by sutures and color differences. The above interpretation of the clypeus and labrum, which is the one given by Muir and Kershaw, agrees with the nymph and adult condition found in all Tubulifera observed and it also explains the condition found in the Terebrantia. Garman's interpretation of the clypeus and labrum in the Terebrantia presents difficulties when an attempt is made to apply it to the conditions found in the Tubulifera.

Compound Eyes.—The compound eyes of Heliothrips (fig. 12, 13 and 19) are present in the nymph as small, oval areas on the lateral aspects of the head-capsule in the dorso-caudal region. There are five, round, indistinct bodies in each elevated area. In the nymph of Cephalothrips (fig. 17 and 18) two similar, elevated, small, oval areas are present on the cephalo-lateral aspects of the head, but these possess no facets or round bodies. In the adult stage of both species (fig. 1, 2, 5, 7, 8, 9, and 11) there is a large, reniform area filled with facets, covering the latero-cephalic areas of the head. In the adult of Heliothrips the eyes protrude beyond the general curvature of the head, the facets are scattered, few in number and variable in size. From a ventral view six large, opaque facets can be seen. These larger facets retain their muddy brown color, and do not become clear and transparent as do the remainder

of the facets when they have been treated with potassium hydroxide. In the adult of Cephalothrips the eyes do not protrude from the head-capsule, the facets are numerous, clear, and all approximately of the same size.

OCELLI.—The ocelli as far as observed are three in number. They are situated on the dorsal aspect of the head between the compound eyes in the form of a triangle with the median ocellus on the cephalic side. In the two species figured the ocelli of Heliothrips (fig. 7) are clear oval bodies located on a small, elevated, triangular area, while the ocelli of Cephalothrips (fig. 9) are clear, circular bodies, larger than the facets of the compound eyes, more distant from each other than those of Heliothrips and not elevated above the general plane of the head-capsule. No traces of ocelli were found in the nymphs.

TENTORIUM OR INTERNAL HEAD-SKELETON.—Under this heading only those internal structures found in the head that pertain to the tentorium will be considered. For other internal parts the discussions on the maxillae, pharynx and salivary glands should be consulted.

One finds within the head of a generalized insect a definite arrangement of rod- and plate-like structures which go to support the internal organs and furnish points of attachment for muscles. These rods or plates extend from three pairs of openings on the head-capsule. These openings are known as the invaginations of the anterior arms, dorsal arms and posterior arms of the tentorium. The invaginations of the anterior arms are usually associated with the lateral margins of the clypeus and with one of the points of articulation of the mandibles. The invaginations of the dorsal arms are associated with the points of attachment of the antennae. The invaginations of the posterior arms are associated with the occipital foramen, and the point of attachment of the maxillae. These generalized relations become modified in the various orders and families of insects. The invaginations may disappear and the rods and plates undergo striking changes or become atrophied. The important point, however, is that in all orders of insects, so far as observed, the invaginations and the arms of the tentorium are always associated with the appendages named. These associations exist in thrips and an attempt will be made to show that they have an important bearing on the homology of their mouth-parts.

On account of the close relation existing between the Homoptera and the Thysanoptera, a comparison will be made between the internal head-structures of Cicada and those of thrips. Figure 29 is a lateral view of the entire tentorium of Cicada showing the invaginations and the arms. The invaginations of the anterior arms of the tentorium (i. a.) occur at the ventro-lateral ends of the clypeus while the dorsal arms are invaginated (i. d.) just ventrad of the antennae. Between these two pairs of invaginations distinct, thin, broad, chitinized plates extend which are the anterior arms of the tentorium (a. a.). The invaginations of the posterior arms (i. p.) are found on the lateral margins of the occipital foramen adjacent to the maxillary plates described by Muir and Kershaw. These invaginations give rise to the broad, plate-like posterior arms (p. a.) which nearly surround the occipital foramen. A small chitinized rod extends across the occipital foramen between the dorsal ends of the posterior arms. This rod is the body of the tentorium (b. t.) and from its mesal portion two long, slender rods arise which extend cephalad (d. a.) and unite with the invaginations of the dorsal arms (i. d.). These two rods are the dorsal arms of the tentorium. In Cicada the ventral ends of the posterior and anterior arms unite on each side (xc.) and between these united arms there extends across the meson a distinct plate or bridge (zc.). The usual association between the appendages of the head and the tentorium among insects may be found in Cicada; that is, the invaginations of the posterior arms (i. p.) are near the point of attachment of the maxillary, piercing organs with the head-capsule; the mandibles are associated with the anterior arms but on account of their great length and the excessive development of the clypeus, they are not connected near the invaginations of the anterior arms (i. e.) but connect with the head-capsule slightly laterad of the anterior arms near the invaginations of the dorsal arms; and the invaginations of the dorsal arms (i. d.) are adjacent to the antennae.

As mentioned before, the internal head-skeleton of thrips undergoes considerable modification and this is well illustrated in the various heads figured. In the nymph of Heliothrips (fig 12, 13, 19 and 28) the tentorial structures are nearly all present, while in the adult of Cephalothrips (fig. 8 and 33)

extensive atrophy has taken place and those tentorial parts which still remain can only be interpreted by comparison with the more generalized conditions in the nymphs.

On the cephalic aspect of the head of a nymph of Heliothrips (fig. 13) two sets of invaginations can be seen. One pair exists on the ventral margin of the front (i. a.) and the second pair (i. d.) a short distance dorsad of these. Since the invaginations on the ventral margin of the front are close to the lateral edges of the wide clypeus, they actually occur on the lateral aspects of the head-capsule. This is especially true of the invaginations on the right side. Distinct chitinous arms extend between the invaginations on each side (a. a.). The invaginations, as described, are homologous with the two pairs of invaginations on the cephalic aspect of the head of Cicada. The two invaginations on the ventral margin of the front are believed to be the invaginations of the anterior arms of the tentorium (i. a.) while the invaginations dorsad of these are the invaginations of the dorsal arms of the tentorium (i. d.). The rods between the invaginations on each side are the anterior arms (a. a.). Chitinized thickenings (d. a.) extend dorso-caudad from each of the invaginations of the dorsal arms (i. d.) and these thickenings on reaching the caudal margin of the head-capsule turn caudad and run parallel with the caudal margin of the head (p. a.) to the distal ends of the caudal projections (c. a.). On comparison with Cicada the dorso-caudal extensions that project from the invaginations of the dorsal arms to the caudal margin of the head are homologous with the dorsal arms of the tentorium (d. a.) while the chitinized thickenings along the lateral margins of the occipital forearm (p. a.) are considered as homologous with the posterior arms of the tentorium. In thrips the body of the tentorium is wanting, consequently the dorsal arms (d. a.) connect directly with the posterior arms (p. a.). The invaginations for the posterior arms (i. p.) were not identified in any of the thrips examined. In a few cases it seemed as though the invaginations were present near the ventral end of the posterior arms (p. a.) where the thickenings (x.) on the ventral margin of the head-capsule came in contact with the posterior arms. Thus far the tentorium of a nymph of the Terebrantia can be homologized with the tentorium of Cicada.

The differences which occur between the tentorium of a Cicada and a thrips can be largely accounted for in the differences between the head-structures. The head-capsule of a thrips is elongated cephalo-caudad while this extension of the head-capsule of a Cicada is short. Furthermore in a Cicada the clypeus is large and occupies the greater part of the cephalic aspect of the head but this is not so in thrips. The invaginations of the dorsal arms (i. d.) in thrips are apparently not associated with the antennae. This seemingly lost association is undoubtedly due to the excessive cephalic or dorsal growth of the head-capsule. The location of the invaginations of the anterior arms of the tentorium (i. a.) in thrips resembles the location in a generalized insect since they are near the cephalo-lateral corners of the clypeus and not near the distal ends of the clypeus as in Cicada.

The following tentorial structures are present in thrips which are difficult to account for on the basis of the homology with the structures in Cicada. A distinct thickening extends along the caudal or ventral margin of the head-capsule between the caudal projections (x. and z.). This thickening is present in all thrips. In the nymph of Heliothrips the portion of the thickening (x.) between the ventral end of the right anterior arm (a. a.) and the right posterior arm (p. a.) is wanting. The above thickening may be secondary or possibly may be homologized with the union of the ventral ends of the anterior and posterior arms of Cicada (xc. and zc.). In all the thrips examined, distinct, chitinous, ental projections arise from the invaginations of the dorsal arms. These projections are not present in Cicada.

In considering the tentorium of thrips figured in this paper, a distinct atrophy of certain portions and parts can be seen. In the adult of Heliothrips (fig. 1 and 27) a thickening occurs (x. and z.) along the caudo-ventral margin of the head-capsule and from this thickening other thickenings (p. a.) arise which extend to the caudal projections (c. a.) of the head-capsule. Of the anterior arms (a. a.) only the left one is present. The left anterior arm is located in a depressed line extending between the invagination of the left dorsal arm and the recurrent angle on the caudal margin of the front. The dorsal arms (d. a.) are wanting and also the posterior arms (p. a.) except for a small portion on the caudal projections (c. a.) of the

head-capsule. The invaginations of the anterior arms are very indistinct in this species due to the thick, highly chitinized and reticulated nature of the head-capsule. This characteristic also makes it difficult to differentiate the tentorial thickenings. However in Thrips physapus (fig. 3 and 6) the invaginations of the anterior (i. a.) as well as the tentorial thickenings are readily made out in dissected heads that have been stained. The invaginations of the dorsal arms (i. d.) with their ental projections show very clearly in the adult of Heliothrips and likewise in all thrips.

In the nymph of Cephalothrips (fig. 22) a still greater reduction of the tentorium apparently exists. This apparent loss, however, may be due to the fact that it is impossible to distinguish all the parts on account of the extremely thin and membranous nature of the head-capsule. Only the invaginations of the dorsal arms (i. d.) with their ental projections show very clearly. By careful staining one can distinguish a thickening (a. a.) occupying the position of the left anterior arm of the tentorium. This thickening extends from the invagination of the left dorsal arm (i. d.) to the point where the asymmetrical piercing organ (l. md.) unites with the head-capsule. In this feature there is a remarkable similarity between the nymphal head of the Tubulifera and the adult head of the generalized Terebrantia.

The tentorium of the adult of Cephalothrips resembles somewhat that of Heliothrips. In Cephalothrips the anterior arms of the tentorium are atrophied but the invaginations of the dorsal arms with their projections are very distinct and the invaginations of the anterior arms can be identified in dissected material that has been stained, if a careful examination is made of the caudal boundary of the head-capsule (z.) at the point where the lateral margins of the clypeus are in contact with the front. Besides the thickenings that are similar to those of Heliothrips two thickenings extend cephalad (mx. p.) on the lateral areas of the head-capsule. These cephalic-extending thickenings clearly arise from the thickenings (z.) about the caudo-ventral margin of the head-capsule and terminate in enlarged, elevated ends which possess acetabula in which the proximal pieces of the paired, piercing organs (mx.) articulate. One can readily see that these mandibular pillars, as Muir and Kershaw call them, are of a tentorial origin.

A distinct strip (st.) is present on the caudal margin of the head-capsule of Cephalothrips and extends between the short sutures (s.) which arise from the latero-caudal margin. Stained material shows clearly that this area (st.) is structurally different from the head-capsule cephalad of it. On the ends of this area (st.) two depressions are present which are similar in many respects to the invaginations of the tentorium. If these are invaginations of the posterior arms then this is a thickening composed of the union of the posterior arms about the dorsal margin of the occipital foramen. This interpretation is rather questionable since no invaginations of the posterior arms have been seen in the more generalized thrips.

As a conclusion to the above discussion on the internal head-skeleton, the following statements are of importance. The tentorium and the associated mouth-parts of an homopteron such as Cicada can be interpreted on comparison with the same parts in a generalized insect. The arms of the tentorium and their respective invaginations in the nymph of one of the Terebrantia can be homologized with the tentorial parts of a Cicada. On the basis of this homology the specialized and atrophied conditions existing in the adults of the Terebrantia and in the nymphs and adults of the Tubulifera can be interpreted.

Furthermore, on the basis of this homology between the tentorium of thrips and other insects an attempt will be made to demonstrate the association of the mandibles and the maxillae with their respective tentorial parts. This should give conclusive evidence as to the correct interpretation of the two sets of piercing organs. See discussion on mandibles and maxillae for this demonstration.

MOVABLE PARTS OF THE HEAD.

The movable parts of the head will be considered in the following order: antennae, labium, maxillae and mandibles. In the discussion of the movable appendages those of the generalized Terebrantia will be considered first and then the homologous structures of the Tubulifera will be compared with them.

ANTENNAE (fig. 4).—The antennae of the adult of Heliothrips are about twice the length of the head-capsule, eight-segmented and reticulated with chitinous elevations corresponding to the reticulations (rt.) on the head-capsule. The shape, size, reticulated character and the setal arrangement are shown in the figure. Segments one, two, six, seven and eight are of a brownish color similar to the head-capsule while the remaining segments are but slightly pigmented. The distal end of segment four gives rise to a thin, hyaline, two-branched sense cone (s. c.). The sense cones are not present in the antennae of the nymph. Except for this the antennae of the nymph are structurally similar to those of the adult.

The antennae of the nymph and adult of Cephalothrips resemble each other and are of the same number of segments, eight, providing the very small pieces at the distal ends of the nymphal antennae are considered as segments. In the first stages of the semi-pupa (fig. 20) the antennae appear as mere buds at the cephalic margin of the head-capsule. As the insect becomes older, the antennal cases increase in size and length until they extend around the lateral margins of the head-capsule. A late stage of the semi-pupal instar shows segmentation on the distal portions of the antennal cases. The eight-segmented antennae of the adult are about one and one-third times longer than the dorsal aspect of the head-capsule and have a yellow color thruout, except the two basal segments, which are of a brown tinge. The general shape, size and setal arrangement of the segments is shown in figure 10. Segments three, four, five and six each possess at their distal end a pair of simple, hyaline, spine-like sense cones (s. c.). The sense cones are wanting in the nymph.

LABIUM.—The mouth-parts of Hemiptera are fitted for sucking. In this adaptation the labium is modified into a long, trough-like beak, enclosing the bristle-like mandibles and maxillae. The mouth-parts of Thysanoptera are also fitted for sucking. The adaptation in thrips, however, is not confined to the specialization of one part of the mouth, but the clypeus, labrum, maxillary sclerites and labium together form a broad and blunt mouth-cone, enclosing the needle-like mandibles and maxillae. Of these two types of sucking mouth-parts, those of the Thysanoptera more closely resemble a generalized

biting type of mouth. The arrangement of the parts of the mouth-cone, the presence of maxillary and labial palpi and other characteristics in Thysanoptera show this close similarity.

The labium of the nymph and adult of thrips is similar (fig. 60 and 61). The entire convex, caudal area of the mouth-cone is the labium. From a caudal view it is distinctly triangular in outline, with the apex at its distal end and from a ventral or lateral view it is convex. The labium is attached along its lateral margins to the triangular, palpus-bearing sclerites (mx. s.) while its dorsal margin is united with the ventral membranous portion of the prothorax. It is composed of two distinct sclerites separated by a transverse suture (s.). The proximal piece is the submentum (sm.) and the distal piece is the mentum (m.). The mentum has at its distal end a membranous area which gives rise to a pair of small, two-segmented palpi (lb. pl.). The distal margin of the mentum possesses two small, chitinous projections considered by Hinds as paraglossae (pr.).

Heliothrips femoralis.—The labium of Heliothrips (fig. 60) corresponds to the general description. The dorso-ventral length of the labium is about the width of the submentum. The ectal surface of the labium is slightly reticulated.

Cephalothrips yuccæ.—The labium of Cephalothrips (fig. 61) corresponds to the general description. The mouth-cone of Cephalothrips is short, consequently the dorso-ventral length of the labium is less than one-half the width of its submentum (s. m.). The submentum is heavily chitinized along its proximal margin as indicated in the figure. The mesal portion of the suture (s.) between the submentum and the mentum is obsolete, but its lateral ends show distinctly. The two projections or paraglossae at the distal end of the labium are united and form a lip-like structure over which the movable, paired, piercing organs pass. This lip is indicated by shading in figure 8.

MAXILLAE.—A pair of asymmetrical, triangular, palpus-bearing sclerites (mx. s.) are situated on the lateral sides of the clypeus and labrum in the mouth-cone of the Thysanoptera (fig. 1 and 8). The palpi (mx. pl.) of these pieces are usually two- or three-segmented. A comparison of these palpus-bearing sclerites with similar sclerites in Cicada shows that

they are homologous with the so-called maxillary plates described by Muir and Kershaw. The segmented palpi however are wanting on the maxillary plates of the Hemiptera. Their presence in Thysanoptera indicates a more primitive condition and also is conclusive evidence that these sclerites are maxillary in origin.

The lateral margins of the maxillary sclerites (mx. s.) are turned into the mouth-cone, thus giving rise to ento-mesal extensions (et.) or plates. These extensions, toward the distal end of the mouth-cone, unite with the lateral edges of the pharynx and form sheaths or troughs over which the needle-like portions of the paired piercing organs (mx.) pass. This is clearly shown in cross-sections of the pharynx (fig. 38-44 and 51-57).

Two sets of piercing organs are found in the mouth-cone of all Thysanoptera (fig. 22, 27, 28 and 33). The paired, symmetrical set will be considered first because of their relation to the maxillary sclerites. Each one of the paired piercing organs is composed of three parts (mx.). Its distal portion is long, grooved, needle-like, and swollen at the proximal end. The middle portion is short and thick and separated from the distal portion by a distinct suture while its proximal end is connected to the proximal portion by a movable joint. The proximal portion is a heavy piece and in some cases three or four times as long as the middle portion. Also its proximal end articulates against the cephalic edge of the maxillary sclerite (mx. s.) or in an acetabulum on an elevated pillar (mx. p.) arising from the head-capsule. This articulation in all cases is either directly or indirectly associated with the maxillary sclerite. The presence of two movable joints in this piercing organ makes its extension into a straight line possible. This extension occurs when the organ functions. When the paired piercing organs are extended beyond the mouth-cone the grooved, needle-like piercing portions interlock and such a union naturally makes an effective tool. This interlocking is readily seen in sectioned material (fig. 25).

The muscles which bring about the extension of the paired piercing organs (mx.) are attached to the proximal pieces. Each extensor-muscle is connected with the ental surface of the maxillary sclerite and the mesal edge of the proximal piece when the piercing organs (mx.) are within the head-capsule.

The above characteristics concerning the maxillary sclerites (mx. s.) and the paired piercing organs (mx.) may be found in all thrips as far as observed and one can safely infer that the similar parts in all thrips are homologous and should have the same interpretation thruout the order. In a like manner it will be found that a similar homology exists between the asymmetrical piercing organs of all thrips. This homology eliminates the suggestion offered by Muir and Kershaw that in the two suborders of the Thysanoptera a distinct difference of interpretation of the piercing organs might be possible.

Heliothrips femoralis (fig. 1, 2, 5, 12, 13, 19, 27, and 28).—The maxillae of Heliothrips are in general typical of the suborder Terebrantia and accord with the general description of the maxillae just given. The maxillary sclerites (mx. s.) of the nymph and adult resemble each other except that the palpi of the nymph are four-segmented while those of the adult consist of only two long segments. The palpi of some of the more generalized adult Aeolothripidae are four-segmented and thus the four-segmented palpi of the nymph indicate a generalized condition. The maxillary sclerites (mx. s.) are decidedly asymmetrical. This asymmetry is more pronounced in the adult (fig. 1). The proximal ends of the maxillary sclerites of the adult are not in direct contact with the head-capsule. There are distinct membranous areas (me.) between them. In this particular species the membranous areas (me.) continue from the cephalic margin of the maxillary sclerites to the bases of the palpi where the membranes broaden and surround the proximal segments. The membranous strip on the left maxillary sclerite is more extensive than the one on the right. The ento-mesal extensions (et.) arising from the lateral margins of the maxillary sclerites resemble closely the general description of these parts and they can be readily made out in figures 28 and 39 to 44.

The paired piercing organs of Heliothrips (fig. 27 and 28, mx.) are but slightly longer than the maxillary sclerites and this is true of the Terebrantia in general. The structure of their paired piercing organs resembles the general description of these parts. The proximal piece in the nymph is L-shaped and the base of the L articulates along the dorsal margin of the maxillary sclerite (mx. s.). The proximal piece in the adult,

likewise articulates against the cephalic margin of the maxillary sclerite and has an L-shape, but the base of the L is greatly reduced and the erect portion is longer, heavier and of the same thickness thruout. The above relation between the paired piercing organs and the maxillary sclerites is true of all Terebrantia as far as observed (fig. 14, 21 and 32). Since the paired piercing organs in the Terebrantia are directly connected with the cephalic margin or the latero-cephalic corners of the maxillary sclerite, one may conclude, as Garman has already done in his work on Limothrips cerealium, that these piercing organs are parts of the maxillae. If such is the case the paired piercing organs may be modified lacinia as Garman has suggested. According to Garman and other workers these organs consist of only two pieces, but in all species observed three distinct pieces can be found. The suture between the needle-like distal portion and the middle piece is wanting in the figures of other workers.

Karl Jordan and other workers have interpreted the paired piercing organs (mx.) as mandibles. Jordan worked with Heliothrips haemorrhoidalis, a form closely related to Heliothrips femoralis. His proof is largely founded on the statement that the embryonic development shows that these pieces are mandibles. The evidence in support of this statement is wanting in both figures and discussion. He has but one figure of the embryonic condition and in this the relation of the so-called mandibles to the head-capsule and other parts is not clear. The real difficulty with Jordan's interpretation rests in the fact that he has wrongly identified the asymmetrical piercing organ (l. md.) and consequently in his search for mandibles he has from necessity tried to show that the paired piercing organs are mandibles.

The conclusion in regard to the paired piercing organs of the Terebrantia is that they are portions of the maxillae, and the following additional evidence will be presented to substantiate the same.

In the first place, if these paired piercing organs are mandibles, how can one explain their three piece structure? Mandibles usually have only one solid piece, but maxillae on the other hand are composed of several sclerites and upon modification they might assume the conditions found in thrips. As to the exact

homology of these pieces it is difficult to determine. However, on the basis of the maxillae of other insects, one finds that the galea is usually segmented while the lacinia is not. In most sucking insects the galea is present and the lacinia may be wanting. It would seem that the paired piercing organs were galea rather than lacinia as Garman has suggested. For convenience of description the paired piercing organs will be designated as the maxillary setæ (mx.).

Strong evidence is likewise found in the relation existing between the paired piercing organs and the tentorium of the head. The maxillae in generalized insects are associated with the invaginations of the posterior arms of the tentorium and this relation was shown to be true with Cicada. On the basis of the homology between the tentorium of Cicada and thrips it was shown that the thickening about the occipital foramen in the nymph of Heliothrips (p. a.) are homologous with the posterior arms of Cicada. In the nymph and adult of Heliothrips the paired piercing organs are closely associated with the ventral or caudal ends of these thickenings or so-called posterior arms. As mentioned before, no invagination of the posterior arms of the tentorium could be found in this genus of thrips; however, from the close association of the paired piercing organs with the posterior arms of the tentorium we may conclude that the generalized relation between the posterior arms of the tentorium and the maxillae holds for thrips as well as for more primitive insects.

Further evidence is found in the fact that in generalized insects the maxillae are always attached to the head-capsule caudad of the mandibles. As was pointed out in the discussion of the head-capsule of thrips, the mouth-cone has been carried around the head until it is now found at the caudo-ventral portion of the head. As a result the mouth-parts have a cephalo-caudal extension rather than the generalized dorso-ventral direction. This rotation of the mouth-parts means that the maxillae should connect with the head-capsule dorsad of the mandibles. The paired piercing organs of the Terebrantia (mx.) are decidedly dorsad to the asymmetrical piercing organ (l. md.), and it will be shown later that the asymmetrical piercing organ is a mandible.

Cephalothrips yuccæ.—The maxillae of Cephalothrips (fig. 8, 11, 17, 18, 20, 22, and 33) are typical of the suborder Tubulifera. The maxillary sclerites (mx. s.) of the nymph (fig. 17) and the adult (fig. 8) are dissimilar in comparative size and symmetry, but both possess a two-segmented palpus (mx. pl.). The long maxillary sclerites of the nymph are nearly symmetrical while those in the reduced mouth-cone of the adult are asymmetrical. This asymmetry in the adult is characterized by a distinct knob (n.) at the cephalic end of the mesal margin of the maxillary sclerite. This knob fits into a notch on the left margin of the clypeus and appears to be a portion of the maxillary sclerite, but a close examination shows that it is only connected with the maxillary sclerite by a narrow strip at its latero-cephalic corner; and a distinct fissure, which extends cephalad and laterad from the point where the clypeo-maxillary suture turns mesad, separates it from the maxillary sclerite. The asymmetrical piercing organ of the adult is associated with the above asymmetry. On comparison with the asymmetry found in the Terebrantia the asymmetry of the Tubulifera is of a decidedly different nature.

The mesal extensions (et.) of the lateral edges of the maxillary sclerites resemble the general description of these parts (fig. 22, 33 and 35). However, a unique modification of these extensions is found in the development of two long, trough-like, cephalic extending arms (mx. g.). These parts serve to guide the long maxillary setæ and have been designated as the maxillary guides. These guides are only present in the Tubulifera, and undoubtedly they have been developed in this suborder on account of the necessity of some kind of a guiding structure for the exceedingly long maxillary setæ. The maxillary guides arise from the mesal part of the sheath (et.) that extends between the lateral edges of the maxillary sclerites at the distal end of the mouth-cone, and project forward into the dorsal portion of the head-cavity to the region of the compound eyes. Cross-sections of the pharynx (fig. 53 and 54) show that in this forward projection they unite with the pharynx. In the nymph they are narrow at their proximal ends but broadly rounded and separate at their distal ends, while in the adult they are trough-like and their distal ends are united in a transverse plate. The long maxillary setæ pass around the

cephalic ends of the maxillary guides and at first are dorsad of the guides. In their caudo-ventral extension they pass along the lateral sides of the trough-like guides and laterad of the pharynx toward the tip of the mouth-cone beyond which the two distal, grooved, needle-like portions interlock and project as a single piercing organ (fig. 25). The maxillary guides show no relation to the tentorial structures of the head.

The paired piercing organs (mx.) of Cephalothrips, except for size, and point of attachment in the adult, resemble the maxillary setæ of Heliothrips. The linear extension of the maxillary setæ in Cephalothrips is due largely to the increased length of the distal and proximal pieces. The large proximal piece in the adult possesses a distinct knob on its mesal margin which serves as a point of attachment for muscles. The resemblance between the maxillary setæ in the nymph or adult of Heliothrips (fig. 27 or 28) and the paired piercing organs in the nymph of Cephalothrips is very striking and important. The feature of significance in the nymph of Cephalothrips is the point of attachment of the paired piercing organs with the cephalic margin of the maxillary sclerites. This shows clearly that the paired piercing organs of Cephalothrips are not only homologous in structure but in point of articulation with the maxillary setæ of the Terebrantia. The paired piercing organs of the Tubulifera are therefore maxillary setæ. The evidence used to prove that the paired piercing organs of the Terebrantia are maxillary in origin will likewise hold for the Tubulifera with the exception of the evidence based on the tentorium, since some of the tentorial structures are wanting in the nymph of Cephalothrips.

The relation of the maxillary setæ to the mouth-parts in the adults of the Tubulifera (fig. 33) is apparently very different from the conditions found in the Terebrantia. The reduction of the mouth-cone explains to a large extent the characteristic modifications of this suborder. In the reduction of the mouth-cone the proximal pieces of the long maxillary setæ (mx.) do not retain their point of articulation with the maxillary sclerites but articulate in acetabula located in special elevated maxillary pillars (mx. p.) on the ental surface of the head-capsule cephalad of the maxillary sclerites. This modification is a result of a mechanical necessity. It would be impossible

for the long maxillary setæ to function if they retained their connection with the reduced maxillary sclerites. However, their connection with the maxillary sclerites is not entirely lost since the thickenings from which the maxillary pillars (mx. p.) arise, extend to the tentorium (x. and z.), which is adjacent to the maxillary sclerites. These thickenings are undoubtedly derived from the tentorium, and since the maxillæ are associated with them they are possibly modifications of the posterior arms (p. a.).

Muir and Kershaw in their work on a species of Tubulifera interpret the paired, piercing organs as mandibles. They give two lines of evidence. In the first place, they show that the asymmetrical piercing organ (1. md.) is a part of the maxillæ, consequently the paired piercing organs must be mandibles. Also they have proved to their own satisfaction by comparison with Rhynchota that the paired piercing organs are mandibles. "The paired setæ we consider as mandibles, homologous to those of Rhynchota." The first part of their evidence will be considered later. In regard to their own statement here quoted there is considerable doubt. They present no satisfactory evidence on this point, and as far as observed, the relations existing in Cicada permit of no such interpretation, as has already been shown. Jordan also studied individuals of the Tubulifera and came to the same conclusions as in his studies on the Terebrantia. The different interpretations of the paired piercing organs in the Thysanoptera of the authors mentioned above has been largely due to an incomplete comparative study of the nymphal and adult stages of both the suborders.

MANDIBLES.—A large, heavy, unpaired piercing organ (1. md.) is present on the left side of the mouth-cone of all thrips (fig. 2, 3, 11, 12, 18, 22, 27, 28, and 33) while on the right side no such organ is found. Berlese figures the asymmetrical piercing organ as occurring on the right side. Undoubtedly this is a mistake for in no case has such an occurrence been recorded by other workers. This asymmetry of mouth-parts is unique among insects. The asymmetrical, piercing organ connects with the head-capsule at the point where the left margin of the clypeus or the right margin of the maxillary sclerite comes in contact with the front. It is composed of

two parts, which are of about the same length. The distal half is a long, heavily chitinized, hollow spine, while the proximal half is broader, hollow and not as heavily chitinized. Cross and longitudinal sections show a distinct lumen extending thruout its length (fig. 26). At the very tip of the spine it is impossible however to be sure that an opening is present. If such an opening is present then it may serve as an exit for the secretions from the glandular tissue within the basal half of the piercing organ. If the lumen is not a duct for the secretions but a blind tube, then one can explain its presence on the basis that it is the place formerly occupied by the hypodermal cells which formed the cuticle of the spine.

Cross-sections of the pharynx show how the asymetrical piercing organ passes along the cephalic side of a left lateral extension of the pharynx (fig. 40 and 41). This left lateral extension is cephalad of the paired extensions over which the maxillary setæ pass, and only occurs on the left side. In the Tubulifera the left maxillary guide helps to form this extension (fig. 53).

There are large muscles attached to the proximal end of the asymmetrical piercing organ. These muscles connect with the dorsal aspect of the head-capsule and on contraction pull the asymmetrical piercing organ (l. md.) into the mouth-cone. The majority of the specimens examined showed the piercing organ protruding from the concave side of the labrum (lr.). Apparently this is its normal position and it is evidently used in making the first puncture thru the outer cells of the plant tissue. After this puncture is made it is probably withdrawn into the mouth-cone, and the long maxillary setæ are then used to puncture the inner and deeper cell-layers. The withdrawal of the asymmetrical piercing organ from the tip of the mouth-cone also permits the plant juices to pass into the pharynx.

On the right side of the mouth-cone a piece (r. md.) is found which is homologous in position to that of the left, asymmetrical piercing organ (fig. 27). In all cases this piece arises adjacent to the front, between the clypeus and the right maxillary sclerite, and extends to the right cephalo-lateral margin of the pharynx and unites with the same (fig. 40). This union is indicated by a distinct suture in cross-sections of the pharynx.

The invaginations of the anterior arms of the tentorium (i. a.) in thrips are always located on the caudal margin of the front and adjacent to the asymmetrical piercing organ and the above-described piece. This evidence undoubtedly shows that this rudimentary piece on the right side is homologous with the asymmetrical piercing organ on the left.

Heliothrips femoralis (fig. 2, 5, 12, 19, 27 and 28.).—The left asymmetrical piercing organ and its right homologous rudiment are typical of the suborder Terebrantia and correspond to the general description given above. These parts in the nymph and adult closely resemble each other. In the nymph (fig. 28) the left, piercing organ is smaller, straighter, and its two halves less differentiated than in the adult (fig. 27). The basal half of the left, piercing organ is connected with the front by a narrow, chitinized neck. This connection is readily seen in frontal sections of the adult and nymph.

The right, rudimentary piece in the nymph and adult extends as a distinct piece between the right cephalo-lateral margin of the pharynx and the front. This piece is homologous with the asymmetrical piercing organ (1. md.) and resembles somewhat its basal half. The distinguishing differences in these two are their size and the union of the right piece with the pharynx. Jordan represents a prominent projection on the right margin of the pharynx of Heliothrips hæmorrhoidalis. This probably represents the asymmetrical piece above described. Garman found in his work on Limothrips a small, right, asymmetrical structure which he considered to be a rudimentary piece homologous with the left, piercing organ. These two pieces Garman designated as mandibles. This interpretation agrees with my own observations. Garman's own words are, "The organ has every appearance of being a mandible. Its form and its relation to the other mouth-parts and to the epicranium all indicate this. Nothing corresponding to this conspicuous organ is apparent on the right side of the head unless a very small, chitinous structure under the edge of the clypeus is a rudiment of the organ for this side." Garman records the structure of the left mandible as consisting of one solid piece. The writer however, considers the left mandible as composed of two parts. At least in all thrips examined a distinct constriction occurs between the distal spine and the large proximal portion, and to all appearances a

suture is located here. Without any question the mandible is hollow, as heretofore explained. The following evidence goes to show that the asymmetrical piercing organs of the Terebrantia are mandibular in origin.

In the first place, as Garman has already mentioned, the structure, position, and point of connection of the asymmetrical piercing organ with the head-capsule are strong mandibular characteristics. It has already been pointed out that the invaginations for the tentorial arms on the front of thrips are homologous with the invaginations of the tentorial arms on the cephalic aspect of the head of Cicada. The invaginations of the anterior arms of the tentorium on the caudal margin of the front (i. a.) are adjacent to the point of connection of the left and right asymmetrical organs (l. md. and r. md.). This relation shows that the asymmetrical piercing organs of the Terebrantia are undoubtedly mandibles since in generalized insects mandibles are usually associated with the invaginations of the anterior arms of the tentorium.

Furthermore, mandibles in generalized insects are always connected with the head-capsule cephalad of the maxillæ. In the nymph of Heliothrips the asymmetrical piercing organs are connected cephalad of the maxillary setæ but in the adult on account of the change of position of the mouth-cone these connections are ventrad of the maxillary setæ. This relation in the Terebrantia shows clearly that the asymmetrical piercing organs are mandibular in origin.

Karl Jordan interprets the left, asymmetrical piercing organ (l. md.) as a modified epipharynx. He bases his conclusion upon embryological studies. The one embryo figured shows the asymmetrical organ as the upper portion of the anterior end of the alimentary canal. The base of the so-called epipharynx is also connected with the head-capsule. He concludes from this figure that when the adult stage is reached the epipharynx loses all connection with the alimentary canal and becomes more firmly attached to the head-capsule. The above hypothesis in regard to the behavior of the epipharynx is contrary to the relations of these parts in other insects. Jordan likewise failed to account for the right, rudimentary piece (r. md.). On the whole Jordan's interpretation is very unsatisfactory, for it does not explain numerous relations here pointed out.

Cephalothrips yuccæ (fig. 11, 18, 22, 26, 33, 34, 35 and 36).—A striking similarity exists between the ental view of the mouth-parts of a nymph of Cephalothrips (fig. 22) and the adult stage of Heliothrips (fig. 27). This similarity is particularly noticeable in respect to the structure and position of the asymmetrical piercing parts. On the basis of this similarity it is possible to derive the correct interpretation of the asymmetrical, piercing organs. The left mandible (1. md.) in the nymph is a long, nearly straight, stout, two-segmented structure and connects with the caudal margin of the front (f.) at the point where the maxillary sclerite and clypeus unite with the head-capsule. Between this point of connection and the invagination of the left dorsal arm of the tentorium a thickening occurs (a. a.). This thickening is the anterior arm of the tentorium and can be seen in carefully stained and dissected material.

The right, rudimentary mandible in the nymph of Cephalothrips is represented by a distinct chitinized thickening between the clypeus and the right maxillary sclerite. The distal end of this thickening (r. md.) unites with the right lateral margin of the pharynx as seen in cross-sections of the adult pharynx (fig. 55 and 56). Figures 33 and 35 do not show this connection because of the spreading of the heads.

The above nymphal evidence clearly demonstrates the homology between the asymmetrical mandibular parts of a species of Tubulifera and those of a species of Terebrantia. The evidence used in proving that the asymmetrical piercing organs of the Terebrantia are mandibles is equally applicable in demonstrating that the asymmetrical parts in the Tubulifera are also mandibles. One exception however occurs in the fact that in the nymph of Cephalothrips the invaginations for the anterior arms have not been identified along with other tentorial structures.

The mandibular parts of the adult (fig. 33) undergo a distinct modification due to the reduction in the size of the mouth-cone. In this change the left mandible (1. md.) retains its position between the clypeus and the left maxillary sclerite, but in so doing the heavy, proximal portion turns and forms a half circle. This modification has resulted in the formation of a distinct notch (n.) in the clypeus and the left maxillary sclerite. It has also resulted in the uniting of the meso-cephalic

corner of the maxillary sclerite and the base of the left mandible. The right mandible in the reduction of the mouth-cone has given rise to a distinct, crook-like, ental projection. The above modifications are typical for the suborder Tubulifera as far as observed.

Muir and Kershaw interpreted the left, asymmetrical piercing organ as a part of the maxillæ in their work on one species of Tubulifera. "The unpaired setæ arises from the left maxillæ and is a part thereof." It is readily understood how such an error came about, since only the adult stage of a single species of Tubulifera was studied. The connection of the left asymmetrical piercing organ in the adult with the left maxillary sclerite is secondary. This connection does not show in the nymph.

PHARYNX.

If one examines the mouth-cone of various species of thrips, a short, heavily chitinized, ham-shaped piece is always found just beneath the clypeus. Stained and sectioned material shows clearly that this piece is a structural modification of the alimentary canal, fitted for sucking and homologous with the pharynx of sucking insects (fig. 5, 6, 19, 27, 35, 38-46, 48, 49 and 52-59). Jordan figures this particular piece and calls it the hypopharynx of the pharynx, while his epipharynx is what we have interpreted to be the left mandible.

Structurally the pharynx consists of one piece except for a small, chitinized, transverse area (t. a.) at the caudo-dorsal end (fig. 46 and 48). However, in respect to size and shape the pharynx is divided into two regions. The ventral half is a small, chitinized tube which opens within the ental groove of the labrum, while the dorsal half widens out into a broad, thick region. The entire pharynx resembles a gourd dipper which has had removed from one side almost one-half of its enlarged portion, and across this cavity there has been placed a concave, elastic membrane (e.) to which muscles (d. m.) are attached. On the caudal side of the enlarged portion there are two small openings. Glandular ducts (d.) pass thru these openings and pour their secretions into the sucking chamber.

When the pharynx is sectioned in one of three planes, frontal, sagittal and transverse, it shows a centrally located canal extending thru its entire length. This lumen starts with

the mouth and continues dorsad of the pharynx as the oesophagus (oe.). Transverse sections of the pharynx show that it is firmly connected on its caudo-lateral aspects with the maxillary guides (mx. g.) and the mesal extensions (et. and 1. et.) from the lateral margins of the maxillary sclerites and the labium. Over the lateral extensions (et.) the maxillary setæ (mx.) pass. The left mandible (1. md.) passes over an extension on the left lateral margin of the pharynx cephalad of the above extensions and the right, rudimentary mandible (r. md.) unites with the right margin of the pharynx. The above extensions and supports that connect with the pharynx serve to hold it in position while the large muscles are dilating its elastic membrane (e.). The above facts in regard to the pharynx hold for all thrips as far as observed.

Heliothrips femoralis.—Figures 38-46 and 58 give a much better idea of the general structure of the pharynx of Heliothrips than a lengthy discussion, consequently only the important and exceptional facts will be pointed out. The transverse sections (fig. 37-44) begin with a section thru the commissures between the supraoesophageal and suboesophageal ganglia and end at the tip of the mouth-cone. Every second or third section, ten microns in thickness, has been figured. In this series the lumen (1.), lateral extensions (et. and 1. et.), piercing organs (mx., 1. md. and r. md.), elastic membrane (e.), and muscles (d. m.) are shown. The connection of the muscles along the meson of the elastic membrane is characteristic of the Terebrantia. The large nucleated and cross-striated muscles, the dilators of the pharynx (fig. 58, d. m.), extend cephalad into the cavity of the head-capsule and unite with the ventral and cephalic areas. Two or more of these large muscle bands unite with a more or less chitinous tendon (c. t.) which arises from the elastic membrane. Besides these long muscles a number of short muscles extend between the small ventral portion of the pharynx and the clypeus.

The food of thrips is of a liquid nature and is sucked into the oesophagus in the following manner, judging from the structure of the parts. The muscles along the meson of the elastic membrane contract and dilate the lumen of the pharynx so that a partial vacuum is formed, and into this cavity is sucked the juice in which the tip of the mouth-cone is immersed. On

the relaxation of the dilating muscles the elastic membrane forces the food dorsad thru the open valve (v.) into the oesophagus. A more detailed account will be given of this process in the discussion of the pharynx of Cephalothrips.

Cephalothrips yuccæ.—In a similar manner, as with Heliothrips, figures 48-57 and 59 show the chief characteristics of the pharynx of the Tubulifera. In its main features it corresponds with the general description of the pharynx but in a few details it shows a greater degree of specialization than the pharynx of Heliothrips. In the first place it is strikingly ham-shaped and comparatively smaller. This difference in size is probably due to the reduction of the mouth-cone. Transverse sections show that the maxillary guides (mx. g.) unite with the pharynx for a short distance, and the extension over which the left mandible passes is the cephalic margin of the left, maxillary guide. The right, rudimentary mandible (r. md.) is not as large as in Heliothrips, however, it still retains its connection with the right side of the pharynx. The lumen (l.) of the pharynx is straight. The most striking difference between the pharynx of Heliothrips and Cephalothrips is in the arrangement of the dilating muscles.

A lateral view and transverse sections of the pharynx show a distinct chitinized plate (pt.) standing on edge along the meson of the elastic membrane (e.). The muscles are confined to the ventral and dorsal ends of this plate and the majority of them are connected to the chitinous tendon (c. t.) at the ventral end. These muscles, so-called ventral dilators (v. d. m.), extend into the head and unite with the vertex. There is a small band of muscles, the so-called dorsal dilators (d. d. m.), which extend between the dorsal end of the plate and the caudo-ventral area of the front. This arrangement of muscles is easily derived from the more generalized type found in Heliothrips. On the whole the form and arrangement of the parts in the pharynx of Cephalothrips would suggest that it is a more efficient organ than that of Heliothrips.

The lumen (l.) of the alimentary canal is cut off by a valve-like structure at the dorsal end of the pharynx (fig. 58a.). A prominent projection (p.) extends from the caudo-dorsal end of the pharynx into the lumen. This projection fits into a pocket (po.) on the opposite side. Under normal conditions

this valve is closed, consequently the lumen of the oesophagus is cut off from the pharynx while the elastic membrane is dilated. In suction the ventral dilating muscles (v. d. m.) contract and pull out the ventral portion of the elastic membrane. This results in the formation of a partial vacuum, and into this space the liquid food is drawn. The dorsal dilators (d. d. m.) now contract and dilate the dorsal end of the elastic membrane (e.). This dilation opens the valve separating the lumen of the pharynx and the oesophagus. While the dorsal dilators are contracting the ventral dilators relax and the ventral portion of the elastic membrane presses upon the enclosed food. This pressure forces the food dorsad in the lumen and then on the relaxation of the dorsal dilators the elastic membrane falls back into its normal position and the food is forced on and into the oesophagus. This completes one stroke or dilation of the pharynx of Cephalothrips.

The dilating muscles of the pharynx (d. m.) of Heliothrips, as before noted, are arranged along the meson of the elastic membrane (e.). This fact, along with the large size of the pharynx and its peculiar bent condition, would indicate that the elastic membrane does not have as distinct a ventro-dorsal dilation as that of Cephalothrips. Possibly the entire central portion of the membrane is dilated at one time and then as the large muscles relax the few strands of muscles uniting with the pharynx in the region of the valve contract and open the lumen. With the valve open and the elastic membrane pressing upon the enclosed food, the plant juice is forced into the oesophagus.

SALIVARY GLANDS.

Two or three kinds of salivary glands (fig. 15, 16, 23, 24, 30, 31, 38-44, 45, 49 and 51-55) are present in thrips and these are all located in the thorax and abdomen. Uzel has figured the glandular portion of the salivary glands located in the thorax and abdomen but does not figure the course of the ducts. In Uzel's figures two kinds of salivary glands are present in the thorax of Aeolothrips fasciatus, a form belonging to the suborder Terebrantia, and three kinds of salivary glands are found in the thorax of Trichothrips copiosa, a form belonging to the suborder Tubulifera. The species figured in this paper have only two kinds of salivary glands, which extend into the thorax and abdomen. These two kinds are paired and distinct.

Considerable variation occurs in regard to the exact location of these glands and the position and points of union of their ducts.

One of the two pairs of salivary glands (fig. 15 and 24, 31) in the thorax and abdomen of the two species here considered is long, tubular and more or less homogenous thruout its length 1. s. g.). This pair is located laterad or dorsad of the alimentary canal and continues caudad into the abdomen. Longitudinal sections thru these glands show that they are homogenous, nucleated and apparently syncitial.

The second pair of salivary glands (fig. 16 and 30) are short, thick and more or less irregular in outline and usually confined to the thorax (s. s. g.). The cells of these glands are large and the cell walls are distinct. The nuclei are prominent and stain deeply. The protoplasm of the tissue stains unevenly and is more or less filled with vacuoles. A distinct centrally located lumen extends thruout the entire length of the gland.

The above two pairs of salivary glands give rise to ducts (l. d. and s. d.) at their cephalic ends. The four ducts extend into the head laterad and dorsad of the oesophagus. In the region between the supraoesophageal and suboesophageal ganglia the ducts turn ventrad and continue to the y-shaped chitinous structure (y.) caudad of the pharynx (fig. 23, 45, 49, 58 and 59.). Within this structure or before entering it the four ducts unite into a common duct and this common duct (c. d.) continues ventrad to the apex of the mouth-cone. The secretions from the salivary glands are thus poured into the punctures in the host plant which are made by the mouth-parts. When thrips puncture green leaves or colored flowers the area about the puncture becomes light in color. This discoloration is undoubtedly due to the action of the salivary secretion on the plant tissue.

The y-shaped piece (y.) caudad of the pharynx in all thrips is a characteristic structure. In both suborders this piece is somewhat different in shape (fig. 35 and 47) but it has the same relation to the mouth-parts. There is a distinct muscle band or there may be several bands (mu.) extending between the base of the arms of the y and the dorsal part of the caudal aspect of the pharynx (ph.). Possibly, on contraction, these muscles move the y-shaped piece in such a manner as to control the flow from the salivary glands. The exact homology of the y-shaped

structure is not clear but its general position and structure, its opening into the mouth-cavity and its relation to the salivary ducts would indicate that it is homologous with the salivary syringe of the Hemiptera.

Heliothrips femoralis.—The long, narrow, tube-like glands (fig. 31 and 24) are located laterad of the alimentary canal (l. s. g.) and extend from the metathorax caudad to about the fourth abdominal segment. Figure 24 shows that the gland is narrow and has a straight lumen extending thruout its length. The ducts from these glands (fig. 31, l. d.) are enlarged and located dorsad of the oesophagus in the region of the prothorax and mesothorax. The enlarged portions of the ducts serve as reservoirs for the secretion. The ducts from these similar right and left glands unite with each other before entering the y-shaped structure caudad of the pharynx.

The short, thick, oval glands (fig. 30, s. s. g.) in the thorax are about the length of two segments and located laterad of the oesophagus. The right gland is usually confined to the metathorax and the first abdominal segment. The cells of these glands are exceedingly large and distinctly differentiated. One or two deeply staining, irregular nuclei can be seen in each cell, and the protoplasm of the cells stains more or less unevenly. The ducts from these glands (s. d.) have about the same thickness thruout. In the region of the head they are somewhat larger than the ducts from the above glands in the same region. The duct from the left gland unites with the duct from the right similar gland before entering the y-shaped piece (fig. 40, 45 and 58). Within the y-shaped piece the united ducts from the two kinds of glands join and form a common duct which continues to nearly the apex of the mouth-cone.

Cephalothrips yuccæ.—The long, tube-like glands of Cephalothrips (fig. 15, l. s. g.) are located laterad of the alimentary canal and extend from the prothorax into the first or second abdominal segment. These glands are homologous with the long, tube-like glands in Heliothrips, but they are thicker and have a sinuous lumen thruout their length. The cell consistency is about the same as in Heliothrips. The ducts extending from these glands into the head are very small and not dilated in the thorax.

The short, thick glands (fig. 16, s. s. g.) in the thorax of Cephalothrips are usually confined to the mesothorax and metathorax and located laterad of the alimentary canal. These glands are homologous with the short, thick glands of Heliothrips. In Cephalothrips these glands are longer and made up of smaller cells filled with vacuoles and granulated areas. The ducts from these glands (fig. 23) are of the same consistency thruout and only slightly larger than the ducts from the long tubular glands. The union of the salivary ducts in the head is somewhat different from that of Heliothrips. The ducts (fig. 23, 49, 52-55 and 59) of one side (l. d. and s. d.) unite and these united ducts meet in the center of the mouth-cone and form a common duct (c. d.) before entering the y-shaped piece.

HEAD-GLANDS.

A distinct, multinucleated and deeply staining tissue (h. g.) is present in definite parts of the head and mouth-cone of thrips and so far as known is described here for the first time (fig. 26, 38-43, 45, 49, 51-55, 58 and 59). This tissue, as far as can be determined, is of a glandular nature and it will be here designated as the head-gland. Its histological structure is different from that of the thoracic glands. Numerous and coarsely granulated nuclei are present; the cell walls cannot be differentiated; the protoplasm stains unevenly and no lumen could be identified. This tissue is most abundant in the members of the suborder Terebrantia. In Heliothrips (fig. 26, 38-43, 45 and 58) it occurs in three distinct regions. The most prominent massing occurs cephalad of the pharynx (h. g.) on the two sides of the dilating muscles. The extent and shape of these two masses varies considerably but the figures of the transverse sections and the lateral views of the pharynx show the usual distribution in this area. Distinct ducts (d.) arise from the dorsal ends of these masses and extend around the lateral sides of the oesophagus and turn ventrad and enter the two small openings on the caudal aspect of the pharynx (fig. 27, 45, 46 and 58). If the above masses are glandular then one can readily see how their secretions may be poured into the pharynx and aid in digestion. Besides the above glandular masses cephalad of the pharynx, similar tissue is present at the proximal end of the left and right mandibles.

The small mass on the left side (fig. 26) projects for a short distance into the hollow cavity of the left mandible. This is not the case with the mass adjacent to the right, rudimentary mandible. These two small masses are connected with the masses above described by means of fine ducts (du.). The exact extent of these ducts has not been definitely determined. It is possible that they unite with the ducts entering the pharynx. It is also possible that the secretions from the small mass within the left mandible passes out thru the minute lumen of the mandible. In the concave portion of the labrum small masses of tissue are present which resemble the above so-called glandular tissue. The extent of these masses varies and as yet no ducts have been observed in connection with them.

In Cephalothrips (fig. 48, 49-51, 55 and 59) the above supposed glandular tissue of the head is present but it is not so extensive. Two distinct masses can be identified cephalad of the pharynx and these give rise to ducts (d.) that empty into the pharynx as in Heliothrips. Also a small mass of similar tissue is located at the base of the left mandible but no such mass is found on the right side near the right mandible. No glandular tissue was found in the concave portion of the labium as in Heliothrips.

SUMMARY.

1. The general arrangement of the head and mouth-parts of the Thysanoptera and the Hemiptera is similar.

2. The resemblance between the mouth-parts of Thysanoptera and Orthoptera is apparently closer than the resemblance between the mouth-parts of Hemiptera and Orthoptera.

3. A comparison of the different structures of the two suborders shows clearly that the suborder Terebrantia is more generalized than the suborder Tubulifera.

4. The mouth-parts of thrips are fitted for sucking.

5. The parts of the mouth are in the form of a cone which encloses the piercing organs. The cone is composed of the clypeus (cl.) labrum (lr.), maxillary sclerites (mx. s.) and labium (lb.).

6. The mouth-parts of thrips are asymmetrical.

7. The asymmetry of the clypeus (cl.) and the maxillary sclerites (mx. s.) in the two suborders is of an entirely different nature.

8. The left asymmetrical piercing organ (l. md.) is the left mandible and the right, rudimentary piece (r. md.) extending between the pharynx (ph.) and the front (fr.) is the right, rudimentary mandible. These mandibular parts are present in all thrips as far as observed.

9. A pair of maxillae are present in all thrips. Each maxilla is divided into two parts; the asymmetrical or symmetrical, palpus-bearing, maxillary sclerite (mx. s.) and the symmetrical maxillary seta (mx.).

10. The tentorial structures in the nymph of Heliothrips can be homologized with the tentorium of Cicada. On the basis of this homology the greatly reduced tentorium of adult thrips can be interpreted.

11. The usual association between the tentorium and the mouth-parts in generalized insects is present in thrips and aids in interpreting the piercing organs. The maxillary setæ are closely associated with the posterior arms, while the left and right mandibles are associated with the invaginations of the anterior arms of the tentorium.

12. A comparison of the head of the nymph of Cephalothrips and the head of the adult of Heliothrips shows clearly the homology existing between the two suborders in respect to the piercing organs.

13. The semi-pupal stage of Cephalothrips shows a distinct reduction in the mouth-cone. The peculiar shape of the left mandible and the point of attachment of the maxillary setæ in the adult is in part due to this reduction.

14. The pharynx at the anterior end of the alimentary canal is modified into a distinct and characteristic sucking apparatus.

15. Two kinds of paired salivary glands are found in the thorax and abdomen of the two species here figured. The ducts from these glands unite and pass into a y-shaped structure caudad of the pharynx.

16. The tissue in the head, here called head-glands, has a similar structure and a definite arrangement. Ducts can be traced from the majority of these glands to the two small openings on the caudal aspect of the pharynx.

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Ventral aspect of the head of Heliothrips femoralis.
Fig. 2. Left lateral aspect of the head of Heliothrips femoralis.
Fig. 3. Left lateral aspect of the mouth-cone of Thrips physapus.
Fig. 4. Antenna of Heliothrips femoralis.
Fig. 5. Right lateral aspect of the head of Heliothrips femoralis.
Fig. 6. Right lateral aspect of the mouth-cone of Thrips physapus.
Fig. 7. Dorsal aspect of the head-capsule of Heliothrips femoralis.

PLATE II.

Fig. 8. Ventral aspect of the head of Cephalothrips yuccæ.
Fig. 9. Dorsal aspect of the head-capsule of Cephalothrips yuccæ.
Fig. 10. Antenna of Cephalothrips yuccæ.
Fig. 11. Left lateral aspect of the head of Cephalothrips yuccæ.

PLATE III.

Fig. 12. Left lateral aspect of the head of the nymph of Heliothrips femoralis.
Fig. 13. Ventral aspect of the head of the nymph of Heliothrips femoralis.
Fig. 14. Ental view of a maxillary sclerite of Thrips physapus.
Fig. 15. Longitudinal section of the proximal and distal portions of a long, salivary gland of Cephalothrips yuccæ.
Fig. 16. Longitudinal section of a short, salivary gland of Cephalothrips yuccæ.
Fig. 17. Ventral aspect of the head of the nymph of Cephalothrips yuccæ.
Fig. 18. Left lateral aspect of the head of the nymph of Cephalothrips yuccæ.
Fig. 19. Right lateral aspect of the head of the nymph of Heliothrips femoralis.
Fig. 20. Ventral aspect of the head of the semi-pupa of Cephalothrips yuccæ.
Fig. 21. Ectal aspect of a maxillary sclerite of Frankliniella tritici.

PLATE IV.

Fig. 22. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of the nymph of Cephalothrips yuccæ. The parts have been spread and the pharynx omitted.
Fig. 23. The union of the salivary ducts in Cephalothrips yuccæ. The solid lines indicate the structures in a sagittal section, ten microns thick.
Fig. 24. Distal portion of a longitudinal section of the long salivary glands of Heliothrips femoralis.
Fig. 25. Manner of interlocking of the grooved maxillary setae of Cephalothrips yuccæ when projected from the mouth-cone.
Fig. 26. Sagittal section of the left, asymmetrical mandible of Heliothrips femoralis.
Fig. 27. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of Heliothrips femoralis. The parts have been spread and the maxillary extensions (et.) omitted.
Fig. 28. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of the nymph of Heliothrips femoralis. The parts have been spread and the pharynx omitted.
Fig. 29. The tentorium of Cicada septendecim.
Fig. 30. Longitudinal section of the short salivary gland of Heliothrips femoralis.
Fig. 31. Longitudinal section thru a dilated duct of a long salivary gland of Heliothrips femoralis. The distal portion of the gland shown in figure 24.
Fig. 32. Ental view of the right maxillary sclerite of Heliothrips femoralis.

PLATE V.

Fig. 33. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of Cephalothrips yuccæ. The parts have been spread and the pharynx omitted.
Fig. 24. Ental aspect of the left maxillary sclerite of Cephalothrips yuccæ.
Fig. 35. Ental view of the ventral aspect of the mouth-cone of Cephalothrips yuccæ. The parts have been spread.
Fig. 36. Ental aspect of the right maxillary sclerite of Cephalothrips yuccæ.

PLATE VI.

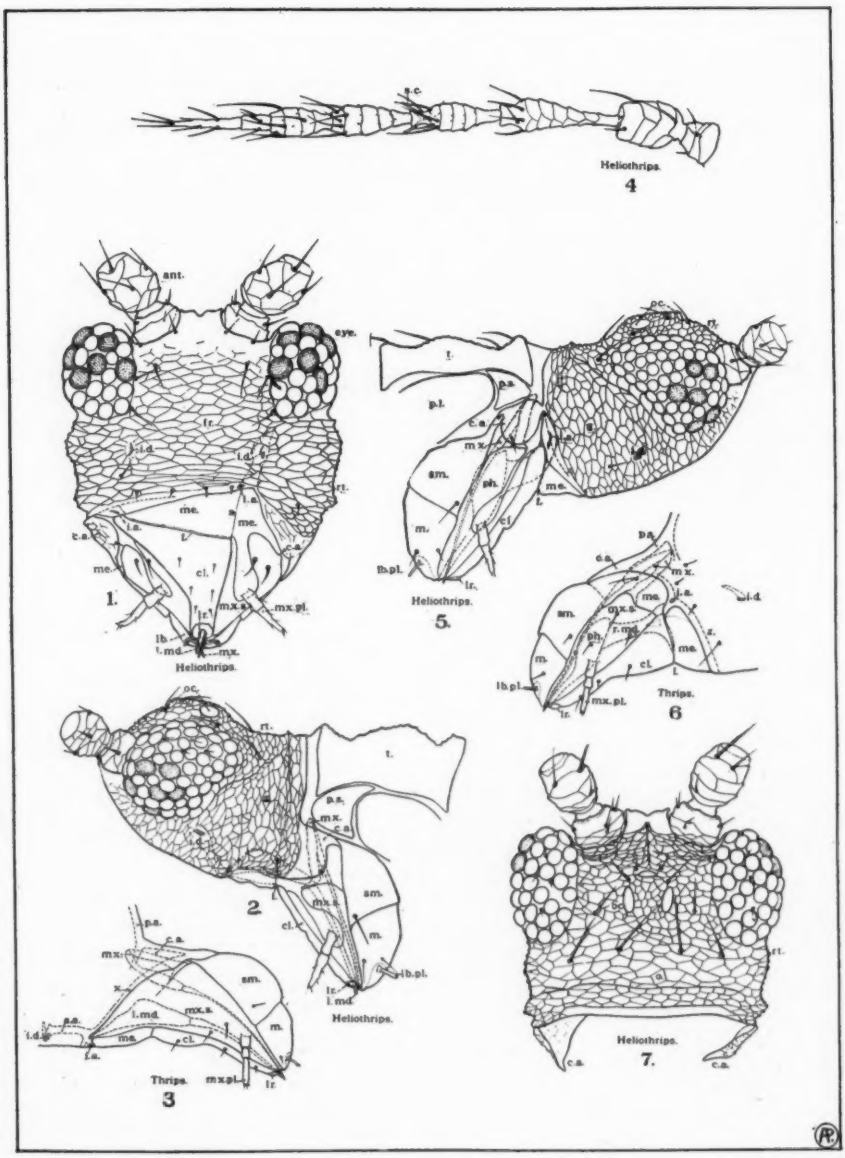
Fig. 37. Frontal section thru the commissures connecting the supraoesophageal and suboesophageal ganglia of Heliothrips femoralis.
Fig. 38–44. Cross-sections of the pharynx from the dorsal end to the tip of the mouth-cone of Heliothrips femoralis. Each second or third section figured.
Fig. 45. Lateral view of the pharynx of Heliothrips femoralis.
Fig. 46. Caudal aspect of the pharynx of Heliothrips femoralis. The extensions over which the maxillary setae pass, have been omitted.
Fig 47. Caudal aspect of the Y-shaped piece located caudad of the pharynx.
Fig. 48. Caudal aspect of the pharynx and labrum of Cephalothrips yuccæ. The extensions, over which the maxillary setae and left mandible pass, have been omitted.
Fig. 49. Lateral view of the pharynx of Cephalothrips yuccæ.
Fig. 50. Frontal section thru the commissures connecting the supraoesophageal and suboesophageal ganglia of Cephalothrips yuccæ.
Fig. 51. Cross-section of the oesophagus of Cephalothrips yuccæ at the point where ducts from the head-glands (d.) pass laterad of the oesophagus in their extension from the head-glands to the two openings on the caudal aspect of the pharynx.
Fig. 52–57. Cross-sections of the pharynx from the dorsal end to the tip of the mouth-cone of Cephalothrips yuccæ. Each second or third section figured.

PLATE VII.

Fig. 58. Sagittal section thru the head and prothorax of Heliothrips femoralis. The salivary glands have been omitted.
Fig. 58a. The valve at the dorsal end of the pharynx of figure 58 more enlarged.
Fig. 59. Sagittal section thru the head and a portion of the prothorax of Cephalothrips yuccæ. The salivary glands have been omitted.
Fig. 60. Caudal aspect of the labium of Heliothrips femoralis.
Fig. 61. Caudal aspect of the labium of Cephalothrips yuccæ.

LIST OF ABBREVIATIONS.

a. a.	Anterior arms of the tentorium.
al. c.	Alimentary canal.
ant.	Antennae.
c. a.	Caudal projections or arms.
c. d.	Common duct of the salivary glands.
cl.	Clypeus.
co.	Commissure.
c. t.	Chitinous tendon.
d.	Duct of the head-glands.
d. a.	Dorsal arms of the tentorium.
d. d. m.	Dorsal dilating muscles of the pharynx.
d. l.	Dilated lumen.
d. m.	Dilating muscles of the pharynx.
du.	Duct from glandular tissue near mandible.
e.	Elastic membrane.
et.	Ental extensions of the maxillary sclerites.
f.	Fold in the clypeus.
fr.	Front.
g.	Gena.
h. g.	Head-glands.
i. a.	Invaginations of the anterior arms of the tentorium.
i. d.	Invaginations of the dorsal arms of the tentorium.
i. p.	Invaginations of the posterior arms of the tentorium.
l.	Lumen.
lb.	Labium.
lb. pl.	Labial palpus.
l. d.	Duct of the long, salivary gland.
l. et.	Ental extensions of the labium.
l. md.	Left mandible.
lr.	Labrum.
l. s. g.	Long salivary gland.
m.	Mentum.
me.	Membranous area.
mu.	Muscle.
mx.	Maxillary seta.
mx. g.	Maxillary guide.
mx. p.	Maxillary pillar.
mx. pl.	Maxillary palpus.
mx. s.	Maxillary sclerite.
n.	Notch.
ne.	Nerve.
o.	Occiput.
oc.	Ocellus.
oe.	Oesophagus.
on.	Oenocyte.
p.	Pharyngeal projection.
p. a.	Posterior arms of the tentorium.
ph.	Pharynx.
p. l.	Prothoracic leg.
po.	Pharyngeal pocket.
pr.	Paraglossa.
p. s.	Prothoracic sclerite.
pt.	Chitinous plate.
r. md.	Right rudimentary mandible.
rt.	Reticulation.
s.	Suture.
s. c.	Sense cone.
s. d.	Duct of the short salivary gland
sm.	Submentum.
s. s. g.	Short salivary gland.
st.	Caudal head-strip.
sub.	Suboesophageal ganglion.
supra.	Supraoesophageal ganglion.
t.	Thorax.
t. a.	Transverse area of the pharynx.
v. d. m.	Ventral, dilating muscles of pharynx.
vt.	Vertex.
x.	Ental thickening on margin of head-capsule.
xc.	Union of the anterior and posterior arms.
y.	Y-shaped pharyngeal piece.
z.	Ental thickening on margin of head-capsule.
zc.	Piece connecting the united arms.



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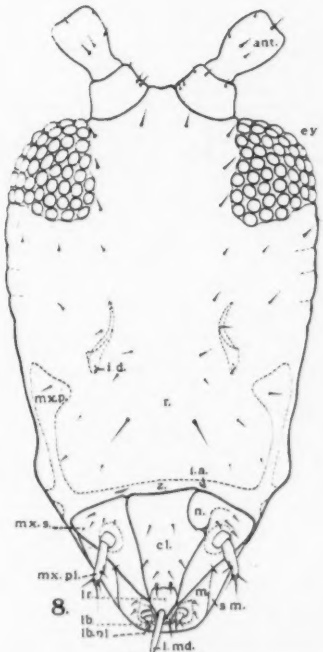

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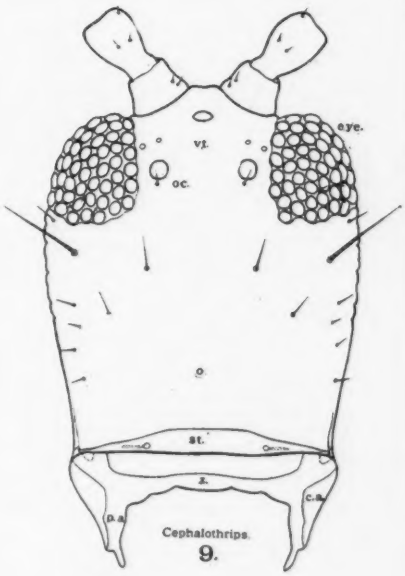

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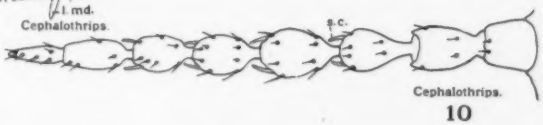

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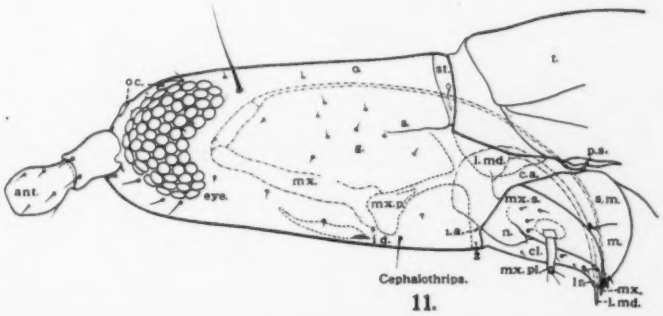

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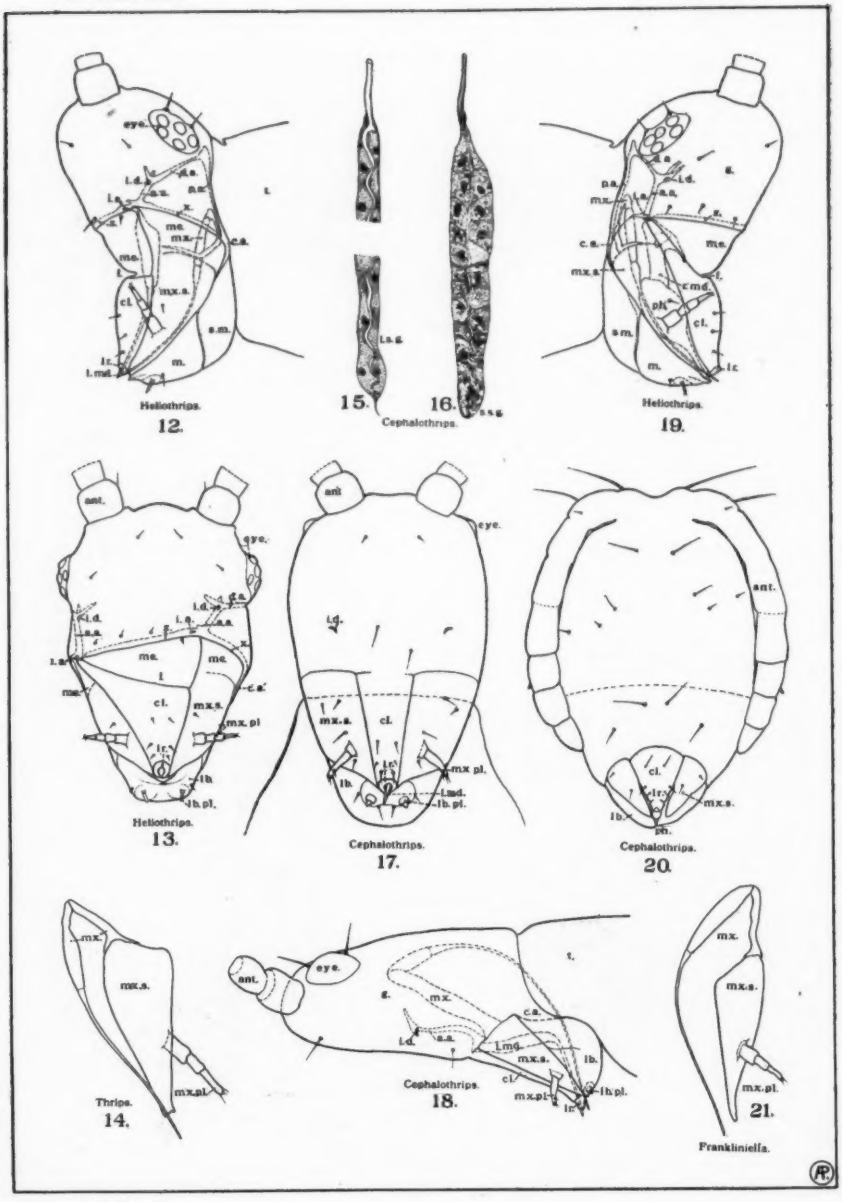

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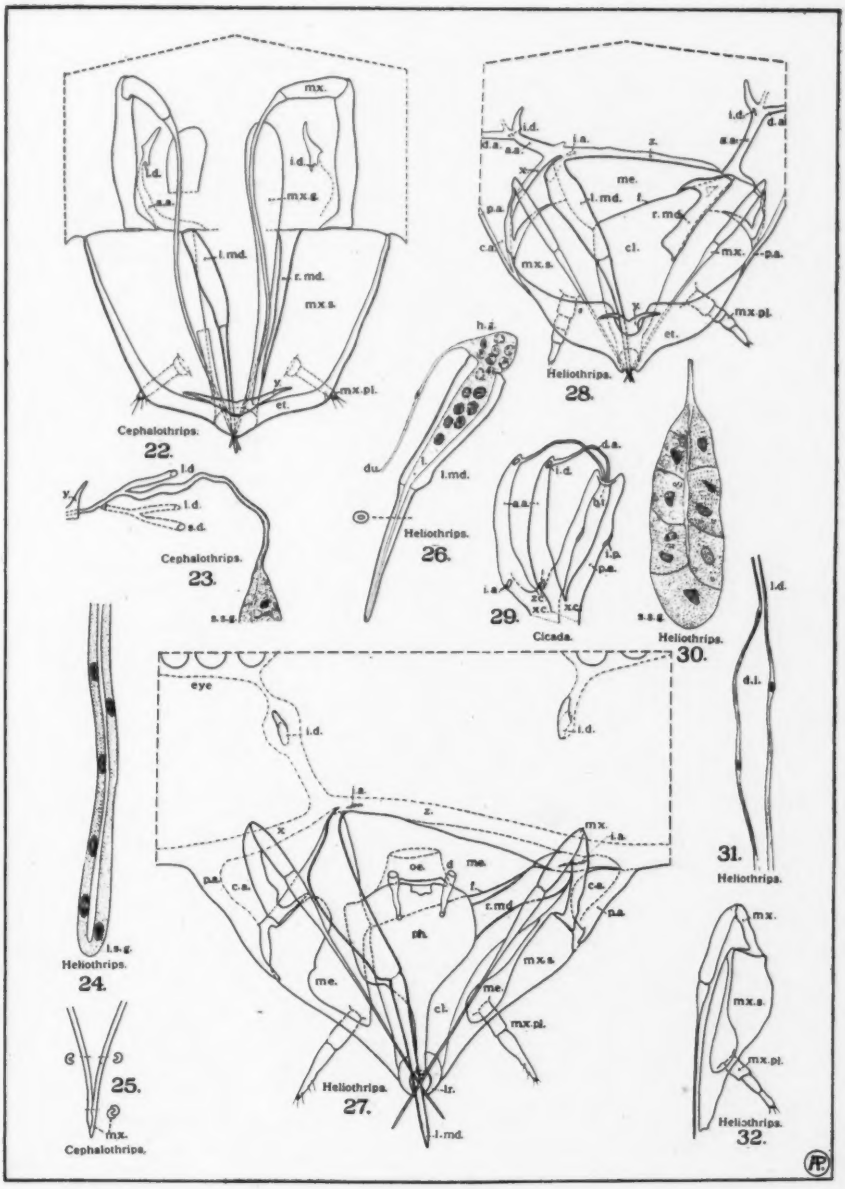

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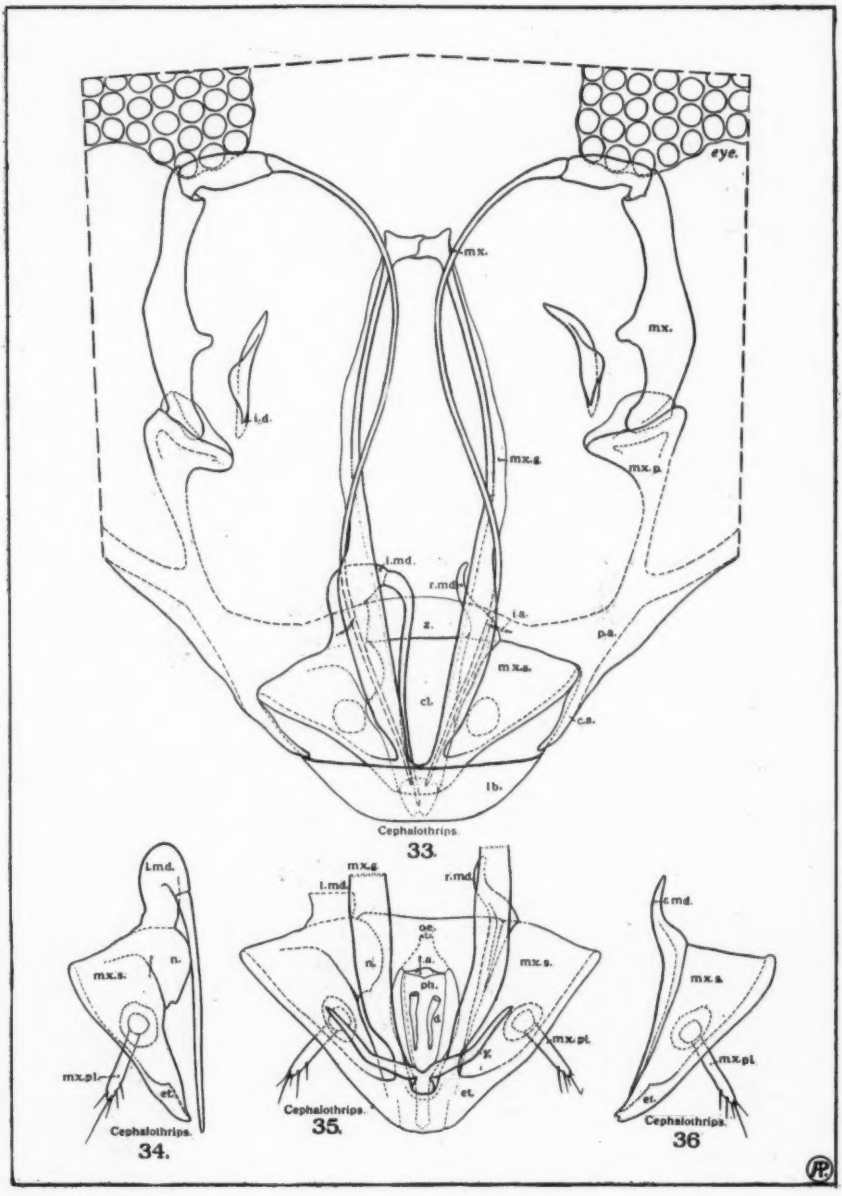

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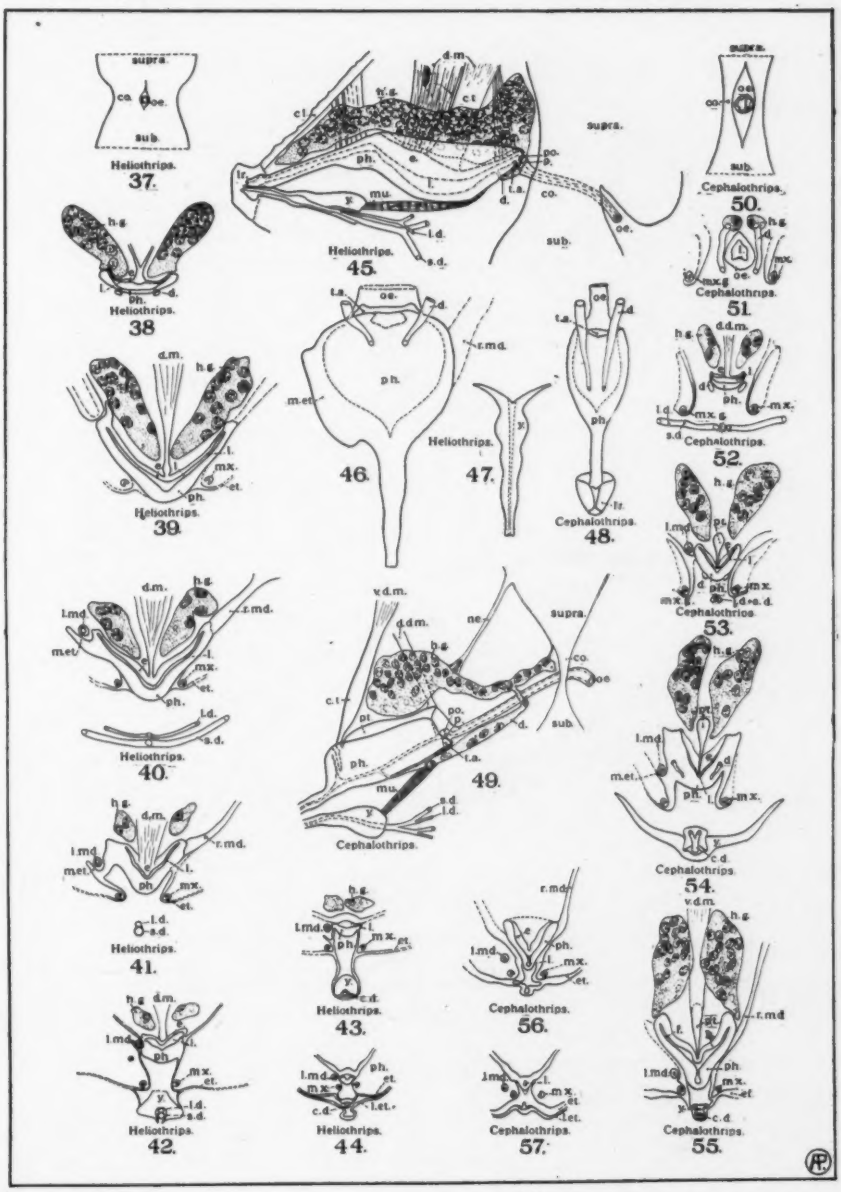

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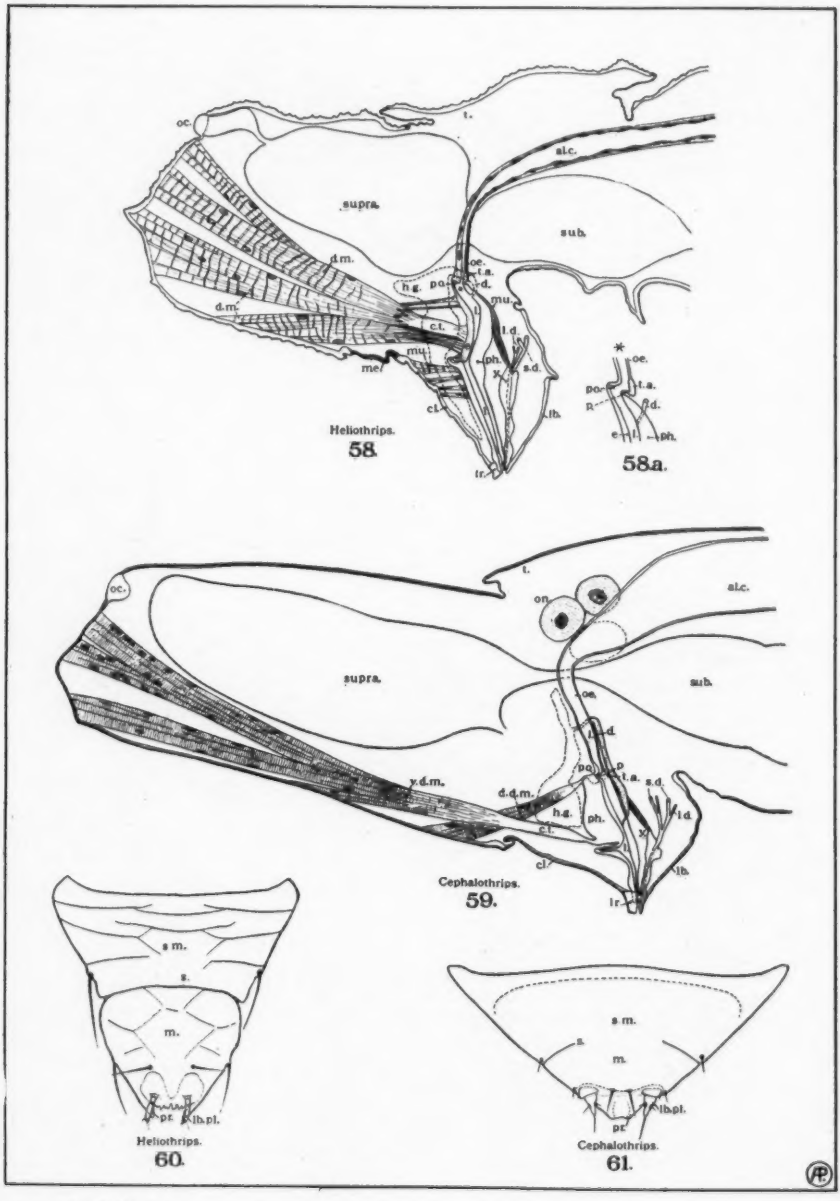


Alvah Peterson.

STUDIES IN DIASPININE PYGIDIA.

By E. W. Stafford.

Up to the present time the practice of staining Coccidæ in toto as an aid to taxonomic work has not been much adopted on this continent. Newstead and Green in their great Monographs, recommend the use of stains, and in their preparation of specimens, stains are used.

The Diaspinæ are classified for the most part on characters of the pygidia of the adult females. In my work with scale insects I found that one's first tentatives toward the practice of staining are apt to be crowned with little positive success, but that after a little experimentation and practice, these artificial colors may be made to enhance the value of the mounts to such an extent as well to compensate for the extra labor involved in their application.

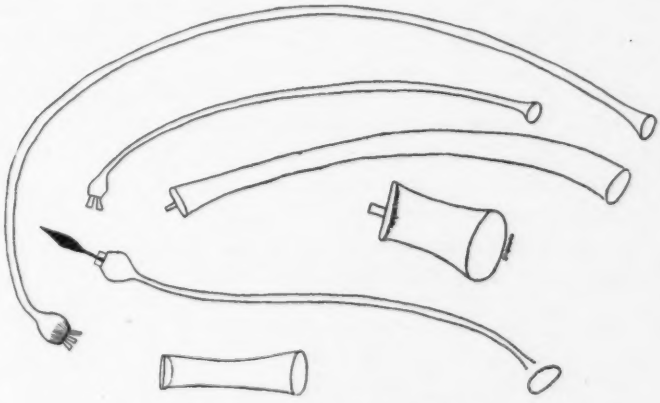


Fig. 1—Types of Tubular Glands

The chitinous paraphyses and the true marginal spines are not shown to better advantage in stained specimens than in those unstained.

The marginal plates, the dorsal pores and the circumgential pores are much more clearly defined in properly stained specimens than in those which have not been stained.

The delicate tubular glands, which are practically invisible in unstained specimens, may be rendered clearly visible by proper staining. These tubules are in general different in different species and constant in the same species. Though they have been ignored by us, they nevertheless present a potentially valuable addition to our list of classificatory characters for the group.

TECHNIQUE.

Females were removed from under their waxy coverings and placed in strong cold aqueous solution of potassium hydroxide and allowed to remain until perfectly clear. This may require from two to five days. The specimens were then placed in a copious quantity of water for a couple of hours to remove all of the potassium therefrom. From the water they were transferred to ninety-five per cent alcohol. From the alcohol, after plenty of time for dehydration, they were transferred to an alcoholic solution of Magentarot, (magenta-red), and allowed to remain about one hundred hours, or until they showed a purple color, but still remained translucent. They then were placed for a few seconds in absolute alcohol to wash off superflous stain and transferred to xylol therefrom.

After a couple of hours they were mounted in balsam or glycerine jelly. The above process entails little labor but extends over considerable time.

The specimens may be boiled in strong potassium hydroxide for from fifteen minutes to half an hour, to procure the same degree of clarity and may be stained in Hämatoxylin solution von Delafield for ten or fifteen minutes. Thus the time of preparation may be much shortened. The former process has, however, given more desirable results.

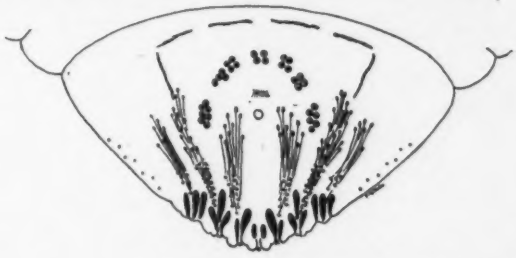
DORSAL-PORES.

The pygidial pores in the Diaspinæ fall into two classes:—Larger, usually elliptic, grouped "macropores," and smaller or minute, circular, single, paired or grouped "micropores."

SPECIES.

Chrysomphalus obscurus:

Micropores, about seven on each lateral margin.

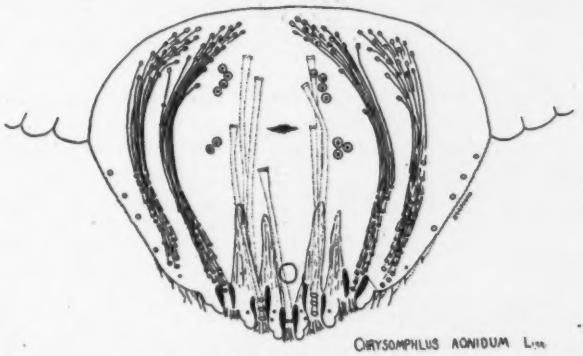


CHRYSOMPHALUS OBSCURUS Comst

Macropores in six groups, giving rise to slender capitate, bi-pistonate tubules. Tubules uniform and in six compact sheaves corresponding to the six groups of macropores from which they arise.

Chrysomphalus aonidum:

Micropores, ten; two between median lobes, two in median lobe, one in second lobe, one on margin beyond third.



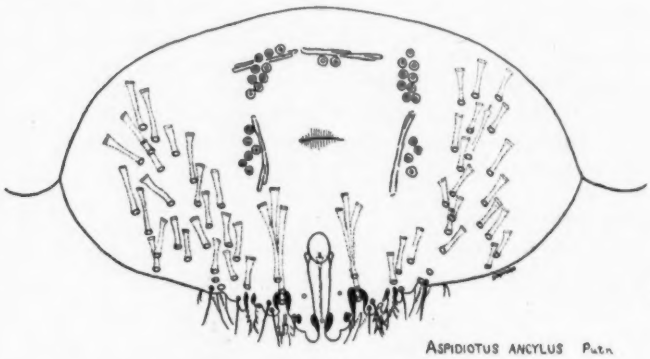
CHRYSOMPHALUS AONIDUM Linn.

Macropores, numerous and in rows. Tubules of two types; one long, sub cyllindric, gradually expanding toward its truncate apex arises from between median lobes. Three similar to above, longer, arise from three macropores between median and second

lobe. About twenty, long, filiform, capitate, tripistonate in compact sheaf, arise from double row of macropores between second and third lobe. A group in all ways similar to above, arises from double row of macropores arising from beyond third lobe. Four, apparently non-tubulate pores close to each lateral margin.

Aspidiotus ancylus.

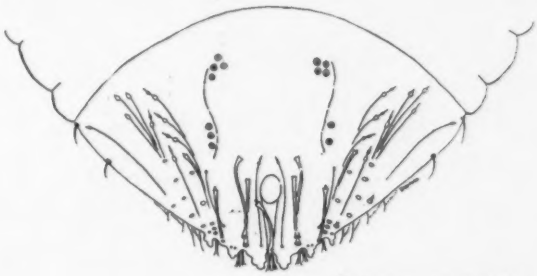
Micropores three—one between median lobes giving rise to slender funnel form tubule uni-pistonate at truncate apex, one in median lobe.



Macropores numerous, scattered, giving rise to short sub cyllindric truncate tubules, which are non-pistonate. Three arising from between median and second lobes are longer than the others.

Aspidiotus brittanicus.

Micropores fourteen—one in median lobe and one between second and third, give rise to minute, filiform, capitate, and sometimes stylate tubules, two in second lobe, one in third lobe, one cephalad of lateral margin of vaginal opening.

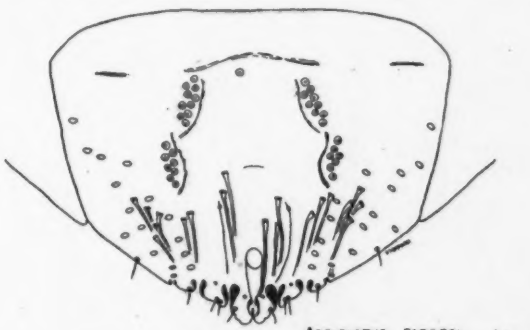


ASPIDIOTUS BRITTANICUS

Macropores scattered. Tubules from same, not uniform. Funnel form with and without terminal pistons, and capitate, armed terminally with fusiform stylets.

Aspidiotus forbesi.

Micropores four—one in median lobe, one in second lobe.

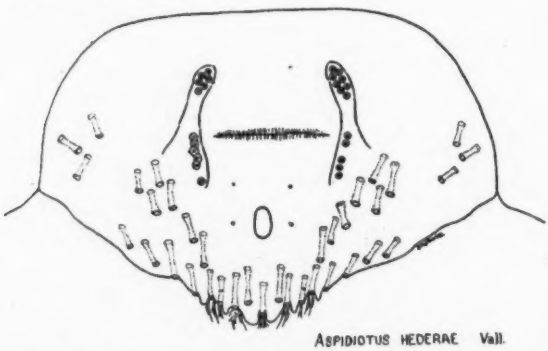


ASPIDIOTUS FORBESI

Macropores scattered. Tubules mostly slender, expanded toward their truncate apexes and non-pistonate. Filiform, capitate, pistonate tubules sometimes visible.

Aspidiotus hederæ.

Micropores six—one between second and third lobes, two at side of anal aperture.

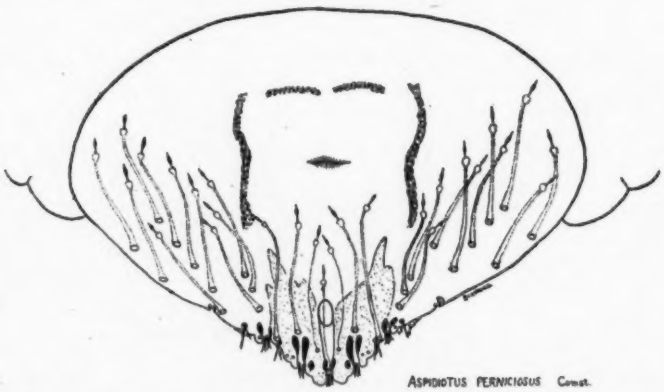


ASPIDIOTUS HEDERAE Vall.

Macropores about thirty-six, at caudal margin and in a rough diagonal row. Tubules short, sub cyllindric, truncate at apexes, which are not armed with pistons.

Aspidiotus perniciosus.

Micropores nine—one between median lobes and one in median lobe, give rise to filiform capitate tubules, two in second lobe, and one in third lobe are non-tubulate.

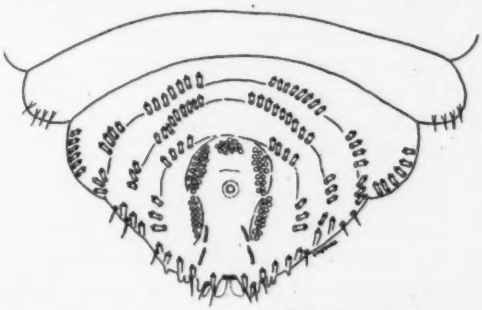


ASPIDIOTUS PERNICIOSUS Comst.

Macropores scattered, give rise to slender tapering tubules, ending capitate. All tubules armed terminally with fusiform stylet.

Aulocaspis rosæ.

Micropores four—two between second lobe and anal aperture. These give rise to minute, short tubules terminating in two capita, the terminal one being armed with a minute piston.



AULACASPIS ROSAE Bouche.

Macropores numerous—situated in transverse rows at vestigial junctures of segments, and giving rise to very short sub cyllindric tubules, which are truncate at tips and armed terminally with short pistons.

NOTE—These studies were made for the most part with Bauch and Lomb ocular number two and one-quarter inch objective.

SUGGESTIONS FOR THE STANDARDIZATION OF TECHNICAL TERMS IN ENTOMOLOGY.*

By G. C. CRAMPTON, Ph. D.

The ever increasing confusiòn in the application of anatomical terminology in entomology, is rapidly producing an absolutely intolerable state of affairs, and unless steps toward reform are soon taken, it will eventually become practically impossible to make use of the present system of terminology, in comparative morphological work. Such chaotic and absolutely needless confusion, would not for a moment be tolerated in any other branch of research, and it is difficult to understand why entomologists are supinely indifferent to a state of affairs which can hardly be said to reflect credit upon their scientific spirit or intelligence. If students of mammalian anatomy, for example, were to apply the term "mentum" to the back of the head in lemurs, to the top of the head in monkeys to the forehead in baboons, to the nose in higher apes, and to the chin in man, the storm of protest which such a course of procedure would arouse, can be easily imagined; yet entomologists may with impunity perpetrate a far more astoundingly flagrant manipulation of anatomical terminology than that cited in the foregoing hypothetical case, and no one is moved to even mildly protest!

Lest the preceding statement should seem slightly overdrawn, one of several similar instances of remarkable entomological usage which suggest themselves, may be cited as an illustration. The term "squama," for example, is applied to the sclerites of the labium and maxilla of Odonata, to the terminal sclerite of the male's genital claspers in Bombidæ, to the lens-shaped "first" abdominal segment of Formicidæ, to one or both calyptra of Diptera, to the tegulæ of Hymenoptera and Lepidoptera, to various squamiform structures of certain insects, to the clothing scales of others, etc. etc., "ad infinitum!" We thus have structures located at opposite ends of the body, together with a generous intersprinkling of intermediate points, to which the term "squama" is applied. If the object of en-

*Contribution from the Entomological Laboratory of the Massachusetts Agricultural College, Amherst, Mass.

tomologists, in this and similar instances, has been to bring about a confusion "thrice confounded," they are certainly to be congratulated upon the signal success which has crowned their efforts!

Among the systematists, an awakening of the modern spirit of scientific exactness is apprent in the attempted standardization of entomological nomenclature, and it is to be hoped that the same spirit of scientific exactness may eventually impel them to adopt some standardization of entomological terminology as well. Since no rules or suggestions whatsoever (so far as I am aware) have been formulated for governing the application of entomological terminology, and since it is apparent that some one must take the initiative in this matter, I would venture to offer the following purely tentative suggestions, in the hope that other workers who have been confronted with the same disconcerting confusion in the application of anatomical terminology, may be moved to contribute to the discussion, or to offer better solutions of the difficulties than those here proposed.

(1). Long established or general usage should be one of the most important factors in determining the application of a term. When, however, established usage is wholly at variance with logical consistency, it should always yield to the latter. For example, according to general and established usage, the term metatarsus is applied to the basal tarsal segment, no matter whether it be that of the metathorax, mesothorax, or prothorax. According to logical consistency*, however, the term *meta*-tarsus should always refer to the entire tarsus of the *meta*-thorax, and of the metathorax alone, since the prefix "meta" delimits all metathoracic structures: e. g. metanotum, meta-coxa, metafemur, etc.

(2). The original usage of a term should always be retained. In other words, if the author of a term applied it to a well defined structure, this term should never be applied to any structures other than those homologous with the one to which this designation was originally applied. It is through the disregarding of this principle that much of the present confusion

*The expression "logical consistency" is used advisedly, since it would be consistent to argue that the designation "pro-podeum" should refer to a prothoracic structure, but this blind carrying of consistency to the extreme, would hardly be logical.

of terminology has arisen, and it is extremely unfortunate that a few necessary exceptions prevent the rigid enforcement of this rule. For example, the designation "thorax" was probably introduced by Linne (Fundamenta Entomologiæ:—Amœn. Acad., Tome 7, p. 143) who applied it to the pronotum of Coleoptera, Hemiptera, etc., and designated the true thorax as the "truncus." It would be wholly impracticable, at present, however, to attempt to restrict the term "thorax" to the pronotum, and to substitute "truncus" for the accepted and well established use of the term thorax.

(3). If terms have been proposed, without clearly indicating to what structures they should be applied, such terms should be regarded as "nomina nuda," and the first definite application of these terms to insectan structures, should be considered as the original one. For example, the terms presternum, sternum (in the restricted sense), sternellum and poststernum, were originally proposed by MacLeay (Zool. Journ. London, Vol. 5, No. 18, 1830) for four hypothetical sternal subdivisions which he neither figured nor described, but merely stated that since they were to be found in *Squilla* and *Julus* (neither of which are insects), they might occur in other "insects." The first application of these terms to insects, was by M'Murtrie (The Animal Kingdom, New York, 1831—a translation of Cuvier's work) who applied the terms presternum, sternum and poststernum to the prosternum, mesosternum and metasternum. (The term sternum, however, had been previously used as a general term applied to the sternal region of all segments.)

(4). A term cannot be used at the same time in a broad and in a restricted sense (i. e. the same term cannot be applied to both the whole, and to one of its parts) without creating confusion. For example, the use of the term sternum in the broad sense, to indicate the entire sternal portion of a segment, and in the restricted sense to indicate one of the several sternites, or sternal subdivisions, creates unnecessary confusion, and only the original use of the term should be retained.

(5). Although the law of priority cannot be strictly enforced in anatomical terminology, it is evidently undesirable to apply any more new terms to structures already supplied with suitable designations, unless it can be demonstrated that the older terms are inappropriate, or are incorrectly applied.

(6). It should be permissible to supercede older terms with new ones, if there is no apparent unanimity of opinion among entomologists as to the application of terms concerning which the author himself was in doubt, or if it is impossible to determine to what structures he intended that his terms should refer. In such cases it is far less confusing to apply entirely new terms, than to risk complicating further, an already sufficiently disconcerting state of confusion.

(7). It should be permissible to make slight changes in older terms, to bring them into harmony with modern usage. For example, the designation "sternopleura" might be modified to "sternopleurite," since the designation "pleura" refers to *both* flanks, while the term "pleurite" refers to a pleural subdivision (as is the case with the so called "sternopleura.")

(8). If the author of a term applied it to wholly different (i. e. non-homologous) structures in the same or different insects, it should be permissible to designate the particular structure to which the term should be restricted.

(9). It is advisable to avoid using a designation composed of two or more terms, for such designations are usually too cumbersome to be of practical application (e. g. "processus pteralis alæ primus," etc.) and when possible, should be superceded by a single concise designation, which may be compound or not.

(10). Hybrid terms (i. e. those compounded from different languages) while permissible, are undesirable, and the number of those already in existence should not be further increased.

(11). Designations expressed in a modern language should have no standing (e. g. "antecoxal piece") and should be superceded by terms of Latin or Greek origin, in accordance with general zoological nomenclature.

(12). In attempting to fix the application of anatomical terminology, the usage employed in some one standard work, such as that of Audouin (Recherches Anatomiques sur le Thorax des Animaux Articules:—Ann. Sci. Naturelles, Tome 1. Ser. 1) might be taken as a basis, just as the tenth edition of Linne's "Systema Naturæ" is taken by the systematists as the basis for establishing entomological nomenclature. An objection to this suggestion is that Audouin was not at all certain as to the application of some of his terms (for example, he applied the term parapteron to wholly different sclerites in

different insects, as pointed out by Crampton, 1914, "On the Misuse of the Terms Parapteron, etc."—Journal N. Y. Ent. Soc., Vol. 22) and in certain instances he applied his terms to wholly unnatural subdivisions of the integument (as is the case with the region which Audouin designates as the "postscutellum," to which attention has been called by Snodgrass, 1909, "The Thoracic Tergum of Insects":—Ent. News, Mar. 1909). The same fault is present to a greater degree in all the earlier works upon this subject, which prevents taking any of them as the standard.

(13). Consideration should be given to the usages employed in standard works of reference (text-books, glossaries, etc.) though unfortunately these authorities do not always agree among themselves, nor are they always logical.

(14). Consideration should be also given to the conclusions of any investigator who has made a thorough study of the literature, and of the homologies of the parts in various orders of insects, and has also presented an impartial resumé of all of the available evidence bearing upon the subject, provided that his conclusions are in accord with common sense and logical consistency—which, in the last analysis, must be the governing principles in the application of anatomical terminology.

The opinion of any individual worker has but little weight, and if effective steps are to be taken toward bringing order out of the present chaos, it must be accomplished through the action of some committee vested with the proper authority to carry out whatever plans may be decided upon. I would therefore propose, as a final suggestion, that the Entomological Society of America appoint a committee of considerable permanence, which would take up this matter in detail, and which would be prepared to decide upon whatever points in anatomical terminology might be presented for its consideration. The conclusions of such a committee, being authoritative, would doubtless be readily accepted by entomologists in general.

RESULTS OF TWENTY-FIVE YEARS' COLLECTING IN THE TACHINIDÆ, WITH NOTES ON SOME COMMON SPECIES.

By J. M. ALDRICH,

Assistant in Cereal and Forage Insect Investigations, Bureau of Entomology.

A recent rather careful inventory of my collection in this family was made the basis of further studies. which seemed of general interest and are presented in this paper.

First a few personal words about my collecting.

I began to collect insects in 1888. In my first two seasons I collected everything without discrimination; but in the spring of 1890 I definitely selected the Diptera as my specialty and began a private collection in them, still for many years continuing to make a general collection for my institution. In the fall of 1890 my attention was directed especially to the Tachinidæ through meeting in Washington Mr. C. H. T. Townsend, who was already specializing in them. For several years I sent him material. The appearance of Coquillett's Revision of the Tachinidæ in 1897 gave a new impetus to my collecting in the family; within a few years he had named a large number of species for me, by the aid of which I gradually acquired sufficient knowledge of the characters to determine for myself within narrow limits. I mention these beginnings merely to show that I have since possibly the first year of the twenty-five paid much more than casual attention to this family.

I should preface my statistics with the remark that I have about the same general conception of species and genera as that of Coquillett in his Revision, and that I use mainly the nomenclature of that work. The total number of North American Tachinidæ in the collection is about 260 species, but I leave out of account in the following figures some 25 species not determined.

Total number of named N. A. species	232
Supposed new species among these	31
Difference, assigned to named species	201
Genera represented	103
Species collected by myself	185
Total number of species in collection from Rocky Mountain and Pacific Slope regions	143

Following are the species collected by myself in the different regions in which I have lived:

Collected in South Dakota, 4 seasons	35
At Lawrence, Kans., first half of 1 season (1893)	19
In Idaho, 20 seasons	91
In California, first half of 1906	21
In Indiana, 1½ seasons	64

The following figures show something about the relative abundance of species:

Represented by one specimen	66
By two specimens	24
By three specimens	23
By four specimens	21
By five specimens	11
By six specimens	13
By seven specimens	11
By eight or more specimens	63

From the figures just given, it appears that about 25% of the species are represented by a single specimen, an equal proportion by eight or more, and that the other 50% fall between these extremes. The strikingly large number represented by a single specimen may be in part explained by the fact that my entomological friends have sometimes favored me with a rarity of which they could spare but one: Professor Melander has in fact often divided with me when he had but two specimens. So I re-examined the 66 cases, and found that only 41 were collected by myself, and 25 by others.

During all the period of my collecting I have been trying to get long series, especially in recent years. Therefore it seemed surprising that I could show eight or more specimens in only 63 species—the more so as in many of these I had only found the insect a time or two in all my experience, as in *Dichocera lyrata* Will., *Paradejeania rutilioides* Jean., and others. Immediately the question arose. How many really common species of Tachinidæ occur in the United States, and which are they?

Taking my 63 species as a tentative list, I asked Messrs. C. W. Johnson and W. R. Walton to make similar ones, enumerating the species which they had found either generally or occasionally common; Mr. Johnson named 52 species and Mr. Walton 71. About the same time while doing some work in the Illinois collection at Urbana I listed 29 named species which were represented by eight or more specimens; and on a brief visit to

Professor Melander I made a very incomplete list of 23 species among his duplicates. This gave me five lists, of which two were largely western and two eastern.

The total number of species mentioned in these lists is 107; of these only 15 were mentioned in all the lists and seem therefore entitled to rank as the commonest Tachnids of the United States; 9 were mentioned four times, and hence may be considered as almost as common; 9 more were mentioned three times, indicating that they are fairly common; 24 were mentioned twice and 50 only once—these two classes have their periods of abundance, as many other species no doubt have, but are not generally or even frequently common. These indications are given as approximations only, conceding that further study of the matter would tend to increase the number of the common group.

Taking them as they are, however, some rather striking facts about their parasitic relations will appear. I give a few notes about the first class, which occurred in all the lists:

Cistogaster immaculata Macq. Adults are collected on flowers throughout the summer, and are in every collection. There is no trustworthy record of the rearing of this species, nor so far as I can find of its European congeners; its evident close relationship with the following species suggests the Pentatomidæ as its hosts.

Gymnosoma fuliginosa R. D. Adults with the preceding, and equally common. Has been bred in Arizona from nymphs or adults of Pentatoma sayi, and again in New Mexico from the same host (the latter an unpublished record of the Bureau of Entomology). It lays an egg on the prothorax of the bug.

Phorantha occidentis Walk. The most abundant of all Tachinidæ; I collected 328 specimens in 20 minutes on October 23, 1914, by sweeping the flowers of Chrysanthemum leucanthemum near La Fayette. Nearly all my dated specimens were taken in September and October, and from flowers of composites. It has been reared on September 11, 1913, by F. B. Milliken, from Nysius angustatus Uhler, one of the False Chinch Bugs (unpublished record). One of its European allies (Phasia hemiptera) attacks adult beetles, inserting an unincubated egg by means of a sharp ovipositor. Occidentis is probably a single-brooded species.

Myiophasia aenea Wied. This is the least abundant of the fifteen; in spite of the fact that it is included in all the lists, I have never seen a good, long series. It has been bred several times from beetle larvæ.

Senotainia rubriventris Macq., and *trilineata* V. d. W. These are always common, especially the latter, on sandy soil in summer, where wasps dig their holes. Presumably they parasitize these Hymenoptera, as their European congeners do, but none have been bred in this country.

Ocyptera carolinæ R. D. Common on flowers in late summer, especially on goldenrod. It has been bred once from a grass-hopper. It makes a fair counterfeit of Ammophila when feeding on flowers, with its black and silvery colors and red abdomen.

Panzeria radicum Fabr. This robust species occurs on flowers from April throughout the summer. It parasitizes caterpillars, and has been found to be single-brooded, wintering in the puparium.

Tachina robusta Townsend. A large species found only in spring, often on willow bloom, or sitting on the bare ground. It has been bred from larvæ of moths, and is presumably single-brooded.

Winthemia quadripustulata Fabr. Undoubtedly our most abundant Tachinid parasite of lepidopterous larvæ, from many species of which it has been bred. The adults are very common on foliage.

Paradidyma singularis Tns. Only moderately but persistently common. Bred from burrowing webworms by Forbes in Illinois (unpublished record).

Gonia capitata De G. A very early spring form, even earlier than Tachina robusta. In my experience, the dark form occurs only in spring, while in late summer there is a less common form with yellow abdomen; this if sustained by more careful study would argue for specific distinctness, corresponding more or less to Williston's species. Bred from cutworms—the spring form.

Microphthalma disjuncta, Wied. Adults found on bare ground in June and July. Not very common westward, perhaps not occurring at all in the Pacific Northwest, although it occurs in the Southwest. Parasitic on larvæ of Lachnosterna and presumably in the Southwest on allied genera. Probably single-brooded.

Archytas analis, Fabr. Adult on sweet clover and goldenrod in midsummer. Has been bred from tent caterpillar and army worm.

Echinomyia algens Wied. Adult with the preceding. Has been bred from a cutworm.

The *second group* of species, mentioned in four of the five lists, is as follows:

Trichopoda pennipes Fabr. This appears to occur from Argentina to about the latitude of Kansas, and still farther north to the eastward, but not in the northwest. It has been bred from Anasa and Leptoglossus, plant-feeding Heteroptera.

Cryptomeigenia theutis Walk. Very widespread but not abundant. The adults of Lachnosterna are attacked, and presumably allied genera in regions where Lachnosterna is not represented.

Linnæmyia comta Fall. Abundant on foliage; has been reared from cutworms, and from Laphygma frugiperda (the latter an unpublished record of the Bureau). This species perhaps more than any other in the second group deserves a place in the first, from its very wide distribution. It has however been bred only a few times.

Euphorocera claripennis Macq. Except for the fact that I did not find this species well represented in the Illinois collection, I should have placed it in the first group; my impression is that it is a close second to Winthemia quadripustulata as a parasite of lepidopterous larvæ; it has been reared from many species.

Metachæta helymus Walk. Persistently common, but not abundant. Adult on foliage. Until the past summer this species had never been bred, but Mr. Gahan and Mr. Hyslop both reared it this year from the Army Worm in Maryland (unpublished records).

Metopia leucocephala Rossi. Adult on low foliage and on the ground. Common throughout the summer. Has not been bred in this country, but in Europe, where the species also occurs, it has been reared from nests of Bembex, Halictus, and Philanthus, burrowing Hymenoptera.

Spallanzania hesperidarum Will. Not generally abundant, though widespread. A butterfly parasite.

Peleteria tessellata Fabr, and *robusta* Wied. Both very common species on flowers throughout the country, all summer long. *Robusta* has been bred from Leucania unipuncta by

Vickery at Brownsville, Tex.; from Chorizagrotis agrestis by Kelly at Wellington, Kans.; and from Paragrotis ridingsiana by Doten at Austin, Nev. (Unpublished records). *Tessellata* is so closely allied that it undoubtedly attacks Lepidoptera, though not yet reared.

Omitting the less common species, there are a few facts to be emphasized in the ones above discussed.

First, among twenty-four commonest North American Tachinidæ, twelve are known to parasitize Lepidoptera, three each the Coleoptera and Hemiptera, one each the Hymenoptera and Orthoptera; while in four the larval habits are unknown, only one of these last however probably attacking the Lepidoptera.

Second, that several of these species are probably single-brooded. Parasitism seems in these cases to have restrained within narrow limits the ordinary, primitive exuberance and rapidity of Muscid development. The economic importance also of the species is materially affected by this limitation.

Third, that the natural history of these species is mostly unknown or at least unpublished. While some progress has been made in studying the internal anatomy of the females and making out the stage of advancement at which the young are deposited, there is a great lack so far of field work on the reproduction, as well as of dissection of infested hosts to ascertain the mode of life of the larvæ. There should be more workers in this field. Merely to find and record a fly in the breeding cage where a cutworm moth was due is but a small contribution, though a useful one, to the biology of the fly. Mr. Walton's interesting published observation on larviposition in Chætophleps setosa Coq., the cucumber beetle parasite,* illustrate the sort of beginnings we must have in order to handle the subject properly. Hence in conclusion I cannot too strongly commend to the rising generation as a research subject the biology of parasitic diptera, in which there are many discoveries to be made, of both scientific and economic importance, and of general interest as well.

My acknowledgments are due to Dr. Webster for permission to use unpublished records, and to Mr. Walton for generously furnishing them in advance of his forth-coming new host index of Tachinidæ.

*Mentioned in his article as *Neocelatoria ferox*.

ON PROPER GENERIC CONCEPTS.

By CHARLES H. T. TOWNSEND.

If any excuse be needed for presenting this subject, it is that we are face to face with the problem of adequate and practical generic concepts in the muscoid flies, and it is a patent fact that the soundness of our taxonomic system depends upon its correct solution.

In approaching this problem it is important to review briefly the work of former systematists, in order to guard against a repetition of their errors. The genera of Meigen's predecessors correspond roughly to our families and subfamilies, those of Meigen to our subfamilies and tribes. These authors do not, therefore, figure in this consideration. We may group subsequent authors as specialists and generalists.

Desvoidy was the first muscoid specialist. He had a close eye for differences, but often showed poor judgment in estimating the value of those differences. No one has ever accused him of confusing distinct forms under one name. His errors lay in attaching too great importance to minor characters subject to variation in the case of species, and in choosing insecure and invalid characters for some of his genera.

Rondani was the next specialist in this group. Although in a sense a general dipterist, he possessed a very special knowledge of the Muscoidea. He, however, misidentified various species of the early authors, due perhaps in large measure to a revulsion of feeling prevailing in his time against the too minute and often misjudged discriminations of Desvoidy. With regard to genera, he revised and extended Desvoidy's system, and his mistakes here are not conspicuous.

Finally Brauer and Bergenstamm, and especially Brauer, abundantly won the honors as specialists in external muscoid characters, and they accomplished this by an intensive study of the external adult anatomy, which led naturally to restricted genera and groups. The only blame that can attach to them is in their ignoring Desvoidy's Myodaires and designating certain invalid genotypes. As intensive students of external characters, it is instructive to note how closely they approached the truth in the majority of their generic and group concepts. Those

cases in which they confused distinct genera or referred them to wrong groups were due to no fault of perception, but rather to the fact that they had no sure guide to the value of certain slight but constant external adult characters. At the present day we are fortunate to possess such guide in the male and female reproductive system, egg and first-stage maggot characters.

The errors of the specialists are, on the whole, comparatively few and not appalling; while, the causes thereof being recognized, their repetition may be avoided. All favored closely restricted generic concepts.

Let us now turn to the muscoid work of those general dipterists who have passed into history. All of these employed broad as opposed to restricted generic concepts. Macquart, Schiner and Wulp are very important and significant in this connection. Walker, Bigot and Coquillett stand more or less apart from them, but are even more significant. None of these authors can claim the title of muscoid specialist.

The generalists attempted to apply the same broad generic concepts to the Muscoidea that they applied to the rest of the Diptera. Without going into lengthy detail, it is enough to state that their mistakes are many and often overshadow the good contained in their results. Their misidentifications of species are extremely numerous. Their wholesale confusion of distinct generic forms was the natural result of no concise generic concepts. Almost throughout, their genera are mixed-genera. They may be said to have practically lacked muscoid generic concepts, for their generic rulings were largely arbitrary and so loose as to admit numerous foreign elements. The true explanation of all this is that they possessed only the most superficial knowledge of their subject. I wish to add that these statements can be fully substantiated.

History, therefore, testifies to the necessity for restricted generic concepts in the Muscoidea. After many years of intensive study of these flies, I can see this necessity more clearly every day. There is no question whatever of the necessity, either in theory or in practice, but I seek to present some tangible and specific reasons in demonstration.

Investigation of this subject demands consideration of several principles, namely, phylogenetic orientation, environmental adaptation including habitus-convergence, inheritance

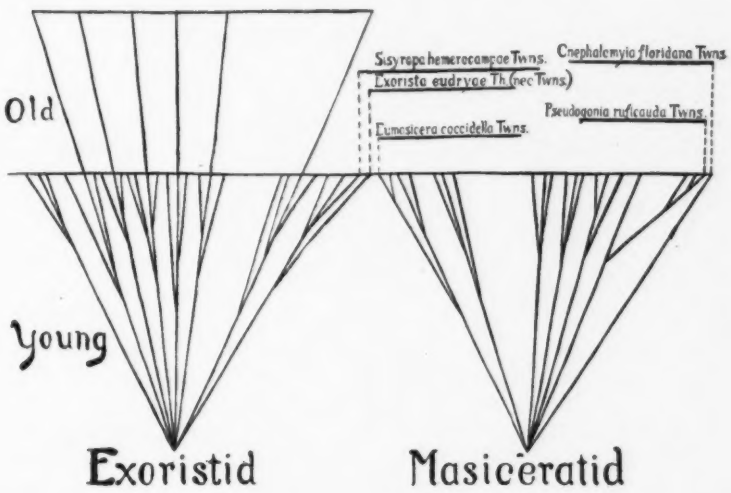
including evolutional trend or anatomical convergence and parallelism, valuation of characters.

In other words, in attempting to fix the proper generic concept in a given group, we must consider the position of that group in the phylogenetic scale (orientation); the response of that group to the factors of the environment (adaptation); and the comparative importance of the various internal and external anatomical structures of all instars for indicating relationships and lines of development both within and without that group (inheritance and valuation). The detailed consideration of these principles leads us to the following reasons for restricted genera in most of the muscoid groups.

(1). Smaller generic value in young stocks owing to greater approximation of the generic stems and their branches, carrying with it the necessity for generic recognition of such stems or types of development from a direct but rather remote common origin, in order to avoid indefinite diagnoses and secure concise generic concepts. Here the principle of orientation figures. The majority of muscoid stocks stand near the limits of present arthropod specialization. They represent the numerous twigs of the phylogenetic tree. As such they are, on the whole, young stocks yet in process of evolution, still approaching their maturity, full of transitionals. These stocks exhibit, each within itself, certain definite lines of development issuing directly from a common source and marking generic stems, which are often connected by transitional species. Groups of generic stems that happen to be connected throughout by transitional species can not be treated as a single genus, on account of their diverse combinations of characters. Such stems must be separately recognized. They can be satisfactorily defined as genera by employing atavic and subatavic characters, or those afforded by structures not especially subject to adaptation. Here the principle of adaptation enters. We have now to provide for the taxonomic disposal of the transitional species. They may be defined as lettered but unnamed subgenera of those restricted genera in common with which they show the most characters of phylogenetic importance. Older stocks do not exhibit such conditions as obtain here. Their generic stems are farther apart, the branches therefrom less numerous, and many of their transitionals have disappeared. (See diagram).

(2). Necessity for generic separation of cases of parallel or convergent development from what are practically remote or very remote distinct origins; that is to say, anatomical parallelism or convergence in generic stems whose distinctness carries far back into the past, but which are in reality of ancient or very ancient though indirect common origin. Here the principles of inheritance and valuation are paramount. Here, if our generic concepts be not very closely drawn, they will allow the entrance of forms which we know positively to belong outside. The reproductive and early-stage characters serve us especially in this connection as a key to the value of the external adult characters. It is understood that a taxonomic system must neither obscure nor do violence to known relationships or lines of development, but must rather present a true phylogenetic picture. (See diagram).

UNRESTRICTED		RESTRICTED	
PROFIT	LOSS	PROFIT	LOSS
Transitional species are easily referred generically	But the extremes of the genus are too dissimilar to be included in an intelligible generic definition	An intelligible generic definition may be drawn up easily owing to the less number of forms included	But transitional species must be referred as lettered subgenera
A small number of generic names is required	But a generic name carries no concrete concept of type, being instead an abstract of dissimilar forms, from which it results that generic comparisons lose their value	A generic name always implies a concrete concept, securing lucidity in generic comparison	But a large number of generic names is required
Correlation of the reproductive and early-stage charters with the external adult charters is not required	But the true relationships and phylogeny of the forms are obscured and evolutional processes ignored, resulting in mixed-genera and misidentifications	Relationships and phylogenetic lines are clearly expressed and evolutional processes recognized, avoiding mixed-genera and misidentifications	But reproductive and early-stage characters are required as a key to the phylogenetic value of the external adult characters



EXPLANATION OF DIAGRAM.

The diverging lines from the two common points represent generic stems including typical species or those of same general type as the stems. Branch lines from the stems represent atypical or transitional species which must be grouped with those restricted genera in common with which they show a preponderance of important characters.

The portion of diverging lines below horizontal dividing line represents young stocks; the portion above same, old stocks. As stocks age the generic stems become farther removed from each other, and transitional species largely drop out.

Cnephalomyia floridana and *Pseudogonia ruficauda* are generically distinct forms, within the Spallanzaniine tribe, with greatly contrasted egg and first-stage maggot, yet so alike in adult as to be almost indistinguishable. Very slight but constant head characters separate them, and the early-stage characters show that the value of these slight adult characters is generic.

Eumasicera coccidella is a Masiceratid whose adult is extremely similar in external anatomical characters to the adults of the Exoristids *Sisyropa hemerocampæ* and *Exorista eudryæ* Thompson (nec Townsend), yet the first possesses microtype eggs while the others possess elongate sub-cylindrical macrotype eggs with short pedicel. All would be referred to same genus on external adult characters, but the small differences in latter are shown by the early stages to be of family value.

While the diagram might be taken to indicate convergence in the adults in these two cases, it is intended merely to illustrate the close similarity in external adult characters of forms shown by early stages to be very distinct. The actual descent has probably been through adult parallelism in both these cases, with juvenile divergence in the Spallanzaniine case, and juvenile-reproductive divergence in the Masiceratid-Exoristid case.

In summing up the evidence, we may present a contrasted statement showing the advantages and disadvantages respectively of employing unrestricted and restricted genera in the Muscoidea. One method must be right and the other wrong. The right method must show advantages unequaled by the wrong method. It becomes a question of balancing profit and loss in the two methods.

The profit in the unrestricted-genus method is seen to be purely nominal; while the loss is manifestly irreparable. In the last analysis the profit turns to loss. On the contrary the profit in the restricted-genus method is of the greatest practical value; while the loss, to say the most, is easily borne. In the last analysis the loss becomes a gain.

In conclusion I would emphasize one fact. The muscoid flies require the nicest and most delicate taxonomic manipulation. The correct separation of their genera and species requires the most painstaking discrimination. Any tendency to lump forms among them is sure to result in bungling and error. An intensive study of the whole superfamily is urgently needed to correct the multitudinous mistakes of former authors, especially those that we have classed above as generalists. Until one has penetrated deeply into the subject, he cannot begin to realize the great number of egregious blunders that have been perpetrated by the generalists in this group. Unless one investigates the subject intensively and impartially, he will be unable to realize the conditions.

BRAUER ON GENERIC VALUES IN THE MUSCOIDEA.

By FREDERICK KNAB,
Bureau of Entomology.

The idea seems to prevail with some American writers on Muscoidea, that generic and specific values can be standardized, that is, that the validity of genera and species should be made dependent upon the amount of difference. Such practice, dictated merely by convenience and the limitations of the worker, manifestly does violence to the facts in nature; it could be ignored as unscientific, were it not so generally advocated. Moreover, the inevitable result of confusing poorly defined species or genera is to invalidate such data as have been published upon them, from both a purely scientific and an economic standpoint. Thus, Dr. Townsend has shown me that flies, which according to the accepted "system" are one species, lay very different eggs or have remarkably distinct first-stage larvæ, that indicate, at the least, wide differences in biology.

It is a well recognized and generally accepted principle, that recent groups have less clearly marked species and genera than the more ancient groups, where the intergradient forms have dropped out. In the Muscoidea we have such a recent group and the great diversity of modifications presented makes the problem of establishing a natural classification, that is, one that follows the phylogeny, an extremely difficult one. Friedrich Brauer, who, in spite of many adverse criticisms, remains one of the greatest exponents of the Diptera, clearly perceived this, as is shown by the following translation of a passage in his early paper on the systematic significance of the larval characters of the Diptera, published forty-five years ago.*

"In surveying the larval forms, one perceives at once that the genera and families of the orthorhaphous Diptera are far more sharply characterized, that is, have a higher systematic value, than the Cyclorhapha, among [the imagines of] which occurs the greatest diversity within the narrowest limits. While with the Orthorhapha the majority of the families can

*Kurze Characteristik der Dipteren-Larven zur Bekräftigung des neuen von. Dr. Schiner entworfenen Dipteren-Systemes. Verh. zool.-bot. Ges. Wien, vol. 19, pp. 843-852 (1869).

even be recognized and sharply characterized in the larval state, those of the Cyclorhapha on the other hand disappear under the pen.

"No one has up to now characterized the subfamilies of the muscids [Muscoidea] in our sense as larvæ; indeed, not even for such obvious forms as Oestrines, Muscines and Sarcophagines can characters be determined. We must leave it to the future to find such characters or to confirm their non-existence. It can be readily understood that the slight characters by which the imagines of these subfamilies are separated, although constant, find none, or a hardly appreciable, expression in the fundamental larval organization."

THE NEMOCERA NOT A NATURAL GROUP OF DIPTERA.

By FREDERICK KNAB,
Bureau of Entomology.

The classification of the Diptera is based upon recognized evolutional principles. The forms in which the larva has a well developed head and the imago multi-articulate antennæ are placed lowest and from them are derived the higher flies, with the system of nerve-ganglia concentrated, headless larvæ and in the imago the number of antennal joints reduced and the venation specialized. Brauer, in his earlier attempts to formulate a natural classification of the Diptera on larval characters, gave primary importance to the reduction of the larval head. He considered phylogenetically lowest those forms in which there is a well developed head with the mouth-parts in normal position, and arranged the other families in sequence in accordance with the degree of reduction of the head, the relative concentration of the nerve centers and the modification of the mouth-organs.[1] Later, when further study had revealed the existence of many refractory elements, he laid greater stress on the progressive concentration of the nervous system, and readjusted his classification with the help of this factor.[2]

Brauer's ideas have been generally accepted and our present-day classifications practically follow him. However, while the transition from the lower to the higher flies along the lines indicated by him may be readily followed in a general way, detailed study reveals many contradictions, more particularly among the lower forms, within the so-called Nemocera. Very naturally these contradictions have led to various attempts toward a more natural grouping, none of which can be pronounced successful; the only ones worthy of mention in this connection are those of Osten Sacken[3] and of Lameere[4].

As already stated, the principles applied to the classification of the Diptera by Brauer are fundamental and must be accepted. But the presence of contradictory elements indicates that some fundamental factor has been overlooked, and such proves to be the case. This factor, more fundamental, as we shall see, than the reduction of the larval head, is the organization of the larval respiratory system. We have in dipterous larvæ several dis-

tinct types of respiratory system. In certain families we find a series of lateral spiracles (peripneustic type), as in normal terrestrial insects. In others the larval tracheal system is laterally closed, open spiracles occurring only in single anterior and posterior pairs (amphipneustic), or in but a single posterior pair (metapneustic). Still other forms show a completely closed tracheal system (apneustic), the skin assuming a respiratory function, sometimes supplemented by specially evolved appendages (blood-gills).

It is evident that the presence of a series of open lateral spiracles represents the normal unmodified type and is therefore a more primitive condition, while the partial or completely closed respiratory system has been acquired in adaptation to an aquatic environment. We must therefore look upon the dipterous larvæ with lateral spiracles as an archaic type and any classification that disregards this fact must necessarily be faulty. From such an ancient type are to be derived the amphipneustic and metapneustic forms. As to the forms with wholly closed tracheæ, it must be pointed out that they may be derived equally well either from the modified types or directly from the peripneustic stock, and there is good evidence that such forms have originated in both ways.

While these conclusions have been reached by wholly independent reasoning, it must be pointed out that the phylogenetic significance of the modifications of the larval tracheal system has been already indicated many years ago. Palmén pointed it out in his classic work on the tracheal system of insects, but he left to others the application of the principle.[5] He argues that the functionless thread-like spiracular branches which exist in forms with wholly or partly closed tracheal system could not have been always functionless. "It is unthinkable that they were rudimentary from the beginning and have originated or been acquired phylogenetically as mere threads. On the contrary, they must have been formerly constituted like the other parts of the tracheal system and have had their full function in order to be able to occur now as rudimentary structures. The larvæ existing at present which possess a closed tracheal system, have therefore formerly had open stigmatal branches in all stages of their existence. This means, in other words: Out of the *relatively primary, open* form of tracheal system of the oldest insects, there has originated

phylogenetically the *relatively secondary, closed* form existing among larvæ of the present time" (1. c., p. 72).

Strangely enough none of the attempts at the classification of the Diptera have taken this fundamental factor into consideration. While the condition of the larval respiratory system in the various families is stated in a perfunctory way in some classifications, its significance seems to have remained wholly unappreciated.*

Let us now survey the result of grouping the families of the so-called Nemocera according to the character of the larval tracheal system, first placing on the one side the forms with the primitive series of lateral spiracles and on the other the specialized forms with partially closed spiracles. Under the primitive peripneustic type we have the families Bibionidæ, Scatopsidæ, Mycetophilidæ, Sciaridæ, Chironomidæ (part) and Cecidomyidæ. The forms with partly closed tracheal system include the Psychodidæ, Culicidæ (part), Ptychopteridæ, Tipulidæ and Rhyphidæ. The apneustic forms do not, as one might expect, form a concrete natural group in culimination of the metapneustic type, but are of diverse origin.

Thus, in the Culicidæ the derivation of the apneustic *Chaoborus* larva is clearly indicated by the existence of a closely related, more primitive form (*Eucorethra*) with open posterior spiracles. On the other hand, we have in the larvæ of most of the Chironomidæ apneustic forms derived from peripneustic stock. This is demonstrated by the existence of peripneustic and apneustic larvæ in the closely related genera *Ceratopogon* and *Culicoides*. Where entire families have apneustic larvæ, as is the case with two within the family-complex here considered, their proper position must be decided by other evidences of relationship. With the two families in question, the Simuiidæ and the Blepharoceridæ, this evidence is so strong that they can be unhesitatingly associated with the peripneustic forms. In fact, in the larvæ of the Simuliidæ the series of lateral spiracles, although minute and not functional, may be still detected.

* Only Osten Sacken has felt, at least to a degree, the fundamental significance of differences in the respiratory system. He excluded *Mycetobia pallipes* from the Mycetophilidæ, on the ground that according to several good observers its larva is amphipneustic, while all other known forms are peripneustic (Proc. Ent. Soc. Phila., vol. 1, p. 151; 1862). I have had no opportunity to examine this larva, but nevertheless believe that the supposed difference rests upon an error of observation.

The adult characters of the groups thus created need not be discussed in detail at this time; suffice it to say that in this light also the groups give the impression of naturalness. But even their superficial consideration forces upon us another fact, and that is that we have in these groups two stocks which have become dissociated in the remote past and are developing along independent lines. For the evolutional picture presented by the adults is just the reverse of the larval one. The group with the more primitive (peripneustic) larvæ shows far the greatest specialization in the adults. This finds its most tangible expression in the reduction of the wing venation—its stronger development in the costal region together with a well developed costal vein, and a weakening of the posterior veins—as we see it in the Scatopsidæ, Simuliidæ, Chironomidæ and Cecidomyidæ. In this last group this line of development reaches its culmination, not only in the greatly reduced wing veins, but also in the reduction of the number of tarsal joints (Heteropezinæ). In the larvæ, too, we find other evidences of extreme specialization along independent lines. As is well known, the larvæ of the Cecidomyidæ have no distinctly chitinized head, there having been a reduction, as in the higher flies; but the persistence of the lateral spiracles, as well as the adult characters, demonstrates the close relationship with the others of the series. Thus we can safely say that in the Cecidomyidæ we have the evolutionary apex of the peripneustic stock.

In the metapneustic series we find the adults exhibiting a far more primitive type. The wing-veins are more numerous, more evenly distributed over the wing-surface and all of nearly equal strength throughout. This condition alone makes it impossible to deduce the metapneustic forms from the existing peripneustic ones. They must have had their origin in peripneustic stock long since extinct, in which the adults likewise were still in an archaic state.

It is thus evident that the time-honored group of Nemocera must be discarded as an unnatural one. The multiarticulate antennæ of the imago, which have been relied upon as of primary value, and the phylogenetic significance of which in a broad way can not be ignored, must be discarded as a group character. The two groups here indicated may be designated by already established terms, originally applied in a much more limited sense, Oligoneura and Polyneura. This seems far pre-

ferable to the creation of new terms, particularly as the definition of those groups has been modified by different workers and as the names are appropriately applicable to the present groups. The status of these groups is now as follows:

Oligoneura	*Polyneura*
Bibionidæ	Psychodidæ
Scatopsidæ	Culicidæ
Simuliidæ	Ptychopteridæ
Mycetophilidæ	Tipulidæ
Sciaridæ	Rhyphidæ
Blepharoceridæ	Orphnephilidæ
Chironomidæ	
Cecidomyidæ	

Postscript.—Since the foregoing was written, Dr. E. P. Felt has called my attention to the possibility of the occurrence of metapneustic larvæ among the Cecidomyidæ. The forms in question are the so-called resin gnats, recently referred by Kieffer to the genus *Retinodiplosis*,[6] whose larvæ live in the resin exuding from the injured twigs of pines. Fortunately the larvæ of these forms have been studied and the necessary data were obtained, for *Retinodiplosis resinicola* O. S. in papers by Comstock[7] and by Miss Eckel,[8] and for *R. resinicoloides* Williams in a paper by this last author.[9] The facts disclosed are highly interesting. These larvæ are structurally peripneustic, but functionally they are metapneustic. The lateral spiracles are minute and not functional, being under normal conditions embedded in the resin, while the last pair (on the eighth abdominal segment) is much enlarged and modified for its augmented duty.

The position of the Blepharoceridæ, as indicated in the foregoing, is confirmed through definite information regarding the organization of the larval tracheal system. No mention of larval spiracles could be found in the more recent literature on the group, and this led to the inference that none occur. In a recent paper Mr. Hugh Scott shows that in *Paltostoma* minute functionless spiracles occur on all six of the body segments of the larva[10] and that such spiracles were already demonstrated on the larva of *Curupira* by Fritz Mueller in his classic paper.[11] Therefore the Blepharoceridæ unquestionably belong in the peripneustic series (Oligoneura).

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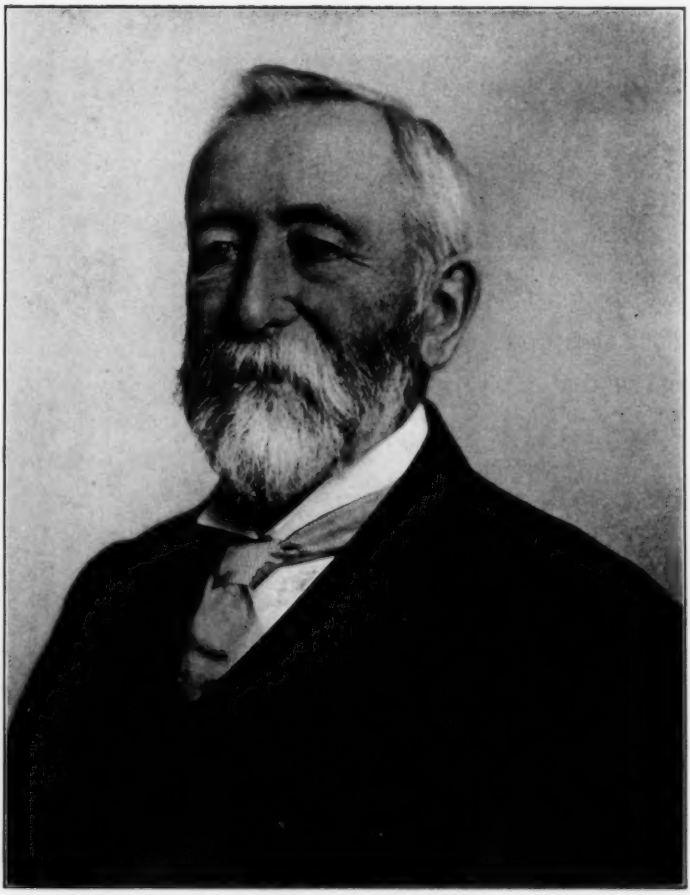


DR. WILLIAM SAUNDERS, C.M.G.

RESOLUTION

On the Death of William Saunders.

The death of William Saunders, C. M. G., L. L. D. on September 13th, 1914, at the age of seventy-nine years removed one of the pioneers of Entomology on this continent.

As one of the founders of the Entomological Society of Ontario in 1863 and of "The Candian Entomologist" in 1868, which journal he edited successfully from 1874 to 1886, and as author of "Insects Injurious to Fruits" published in 1883, he rendered meritorious services to the science of Entomology in its varied aspects. His active interest in the science was only limited by his appointment in 1886 as Director of the Experimental Farms system of the Canadian Department of Agriculture, the organization and development of which stands as an enduring monument to his tireless spirit and industrious zeal.

He was elected a Fellow of our Society in 1907 and as a tribute to his memory and as a public acknowledgment of his conspicuous services in the development of Entomology, which should serve as an example to the younger generation, we recommend that this record be entered in the minutes of the Society and published in the Annals.

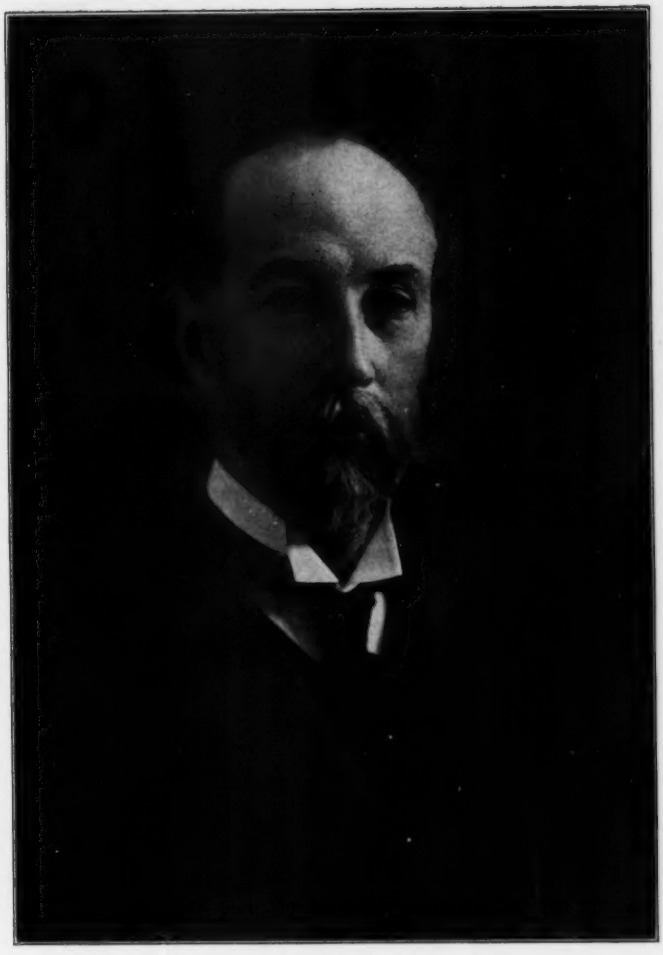
Charles J. S. Bethune,
F. M. Webster,
C. Gordon Hewitt,
—*Committee.*

Henry Herbert Lyman, M. A.

Mr. Lyman and his wife lost their lives in the disaster that befell the steamship "Empress of Ireland" in the St. Lawrence River on May 29th, 1914. He was born in Montreal December 21, 1854, and was a graduate of McGill University. After leaving College he entered his father's firm of wholesale chemists and eventually became senior partner and president of the widely known Lymans, Limited. From his early boyhood he was greatly interested in observing insects and their ways and, though engrossed with the management of an extensive business concern, he devoted his evenings and holidays very largely to the study and collection of Lepidoptera. For nearly forty years he was an active and zealous member of the Entomological Society of Ontario, and rarely failed to attend its annual meetings. During the same period he was the mainstay of the Montreal Branch, whose monthly meetings were for the most part held at his hospitable residence. In 1897 he was elected President of the parent Society, holding office for two years, and in August, 1907 he became a Fellow of the Entomological Society of America. He was also a member of many Entomological Societies in Europe and America.

Mr. Lyman was a constant contributor to the "Canadian Entomologist" and the Annual Reports of the Society, his papers amounting to more than seventy in number. They were for the most part systematic studies in the Lepidoptera, though some were of a less technical character.

For a long time past Mr. Lyman suffered from increasing deafness and of late could only carry on conversation with the aid of an ear-trumpet or by writing. He was, however, always lively and cheerful, and enjoyed attending scientific meetings and other gatherings. He was an excellent example of an amateur Entomologist, who devoted much time and study to the pursuit, and keenly enjoyed the work for its own sake. His large and valuable collections of Lepidoptera were bequeathed to the Museum of McGill University, Montreal, together with a sufficient sum of money to ensure permanent and proper care.



HENRY H. LYMAN, M.A.

The Entomological Society of America desires to place upon record its appreciation of the high services to entomology rendered by the late Mr. Lyman and its sense of the loss sustained through his untimely and tragic death. It is, therefore, ordered that the foregoing memorial be inscribed upon the minutes of the Society as a tribute to their late member and fellow.

CHARLES J. S. BETHUNE,
W. J. HOLLAND,
ELLISON A. SMYTH,
—Committee.

RESOLUTION

ON THE DEATH OF JOHN A. GROSSBECK.

In the death of John Arthur Grossbeck, on April 8, 1914, the Entomological Society of America lost a member who had made considerable additions to the knowledge of North American Lepidoptera and Culicidæ. For about seven years he was an able assistant to the late Prof. John B. Smith at New Brunswick, New Jersey and was entrusted with much of the observational work on the early stages of mosquitoes.

In 1911 he became Assistant at the American Museum of Natural History and was Librarian of the New York Entomological Society. His general knowledge of entomology, great industry and much artistic ability made him an ideal museum man, and he gave conscientious care to the specimens in his charge.

His early death at the age of thirty-one years is a great loss to entomological science, and we, his associates, record our deep sorrow at the departure of a co-worker and friend.

FRANK E. LUTZ,
WM. T. DAVIS,
EDGAR L. DICKERSON,
—Committee.

PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF AMERICA.

Philadelphia Meeting.

The first meeting of the Entomological Society of America was opened on Wednesday evening, December 30th, by President Philip P. Calvert in the large lecture room of the Philadelphia Academy of Natural Sciences for the giving of the Annual Public Address. The speaker of the evening was Professor Stephen Alfred Forbes of the University of Illinois. His subject was, "Ecological Foundations of Applied Entomology." In compliance with the request of the Executive Committee at the Atlanta meeting, Dr. Henry Skinner of the Phildelphia Academy of Natural Sciences presented a "History of the Entomological Society of America." In addition to the history of the Society, Dr. Skinner showed pictures of many of the pioneer entomologists of America. The slides were prepared from photographs, of which the American Entomological Society has the largest collection in America. The speakers were greeted by a large and enthusiastic audience. After the completion of the addresses, the audience adjourned to the Library of the Academy, where the local entomologists entertained the visitors at a smoker. The exceptionally large number of visiting entomologists and the large number of persons in and about Philadelphia interested in collecting and studying insects, made it a great opportunity for the meeting of friends and acquaintances. It was pronounced by all a most enjoyable evening.

The Society was honored at this meeting by the attendance of the pioneer American hymenopterologist and Honorary Fellow of the Society, Mr. Ezra Townsend Cresson.

The meeting for the reading of papers was called to order by President Calvert at 10:00 A. M., Thursday, December 31st., in Class Room D of the Veterinary Building of the University of Pennsylvania. The following committees appointed previous to the meeting were announced.

Committee to draft resolutions on the death of Mr. H. H. Lyman.—Rev. C. J. S. Bethune, Dr. W. J. Holland, and Dr. E. A. Smyth.

Committee to draft resolutions on the death of Mr. J. A. Grossbeck.—Dr. Frank E. Lutz, Mr. Wm. T. Davis, and Mr. E. L. Dickerson.

Committee to draft resolutions on the death of Dr. William Saunders.—Rev. C. J. S. Bethune, Mr. F. M. Webster, and Dr. C. Gorden Hewitt.

The President was directed by motion to appoint the following committees: Committee on Resolutions; Committee on Nominations; Auditing Committee.

The following papers were then read, but in compliance with the action of the Executive Committee only titles are given:

C. P. GILLETTE, Colorado Agricultural College.—Food Habits of Some Colorado Aphids.

CORNELIA F. KEPHART, Cornell University.—The Poison Glands of *Automeris io* Fabr.

NATHAN BANKS, U. S. Bureau of Entomology.—Geographical Distribution of Neuropteroid Insects, together with an Analysis of our Insect Fauna.

PAUL S. WELCH, Kansas Agricultural College.—The Biology of *Nymphula maculalis* Clemens. Read by title.

V. E. SHELFORD, University of Illinois.—Modification of Tiger-beetle Colors by Temperature and Moisture.

L. HASEMAN, University of Missouri.—Life-history, Development, and Work of Unspotted Tentiform Leaf-miner of Apple. Read by title.

EDNA MOSHER, University of Illinois.—Pupal Characters Used in the Classification of the Sphingidæ. Presented by the Secretary.

J. M. ALDRICH, U. S. Bureau of Entomology.—Results of twenty-five Years Collecting of the Tachinidæ.

MORTIMER D. LEONARD, Cornell University.—Notes on Capsid Life-histories.

W. D. FUNKHOUSER, Ithaca High School.—Notes on the Life-histories of certain Membracidæ.

The President announced the following committees:

Committee on Resolutions.—F. M. Webster, Henry Bird, and J. S. Houser.

Committee on Nominations.—J. Chester Bradley, C. P. Gillette, and J. A. Nelson.

Auditing Committee.—Wm. T. Davis, J. H. Emerton, and Frank Morton Jones.

The Society then adjourned to meet at 2:00 P. M.

R. A. COOLEY, Montana Agricultural College.—A Photographic Record of the Development of the Female *Lepidosaphes ulmi* Linn.

C. H. TYLER TOWNSEND, U. S. National Museum.—On Proper Generic Concepts.

ANNA GRACE NEWELL, University of Illinois.—The Homology of the Genitalia of *Benacus griseus*.

On motion the Society adjourned for the remainder of the afternoon so that the members could attend the Symposium being held by the American Society of Naturalists on the subject, "The Value of Zoology to Humanity."

The Society reconvened at 10:00 A. M., Friday, January 1st., 1915 for the Annual Business Meeting and the presentation of the remaining papers of the program.

The Committees appointed to present resolutions on the death of Mr. H. H. Lyman, Mr. J. A. Grossbeck, and Dr. William Saunders presented their reports. They were ordered accepted and printed.

The Secretary presented the following report for the Executive Committee which met in Room 109, Zoological Laboratory University of Pennsylvania, Wednesday, December 30th. There were eight members in attendance, Messrs Calvert, Needham, Hewitt, MacGillivray, Osborn, Banks, Felt, and Aldrich.

REPORT OF THE EXECUTIVE COMMITTEE.

The only matter submitted to the Executive Committee by the Secretary in the interim since the last Annual Meeting was the selection and appointment of Professor Stephen Alfred Forbes to give the Annual Public Address at the Philadelphia meeting.

The following twelve new members were elected by the Executive Committee June 1st, 1914:—

M. T. Smulyan	S. W. Frost
George W. Barber	Herbert Rieckes
J. Howard Gage	Dwight Isely
Sarah E. Maul	Alice A. Noyes
Adolph I. Fabis	William A. Hoffman
R. P. Dow	Philip Garman

The following members have died during the past year:—

J. A. Grossbeck H. H. Lyman
G. T. O. Mueller

The following resignations were presented and accepted:—

Joseph Bridgham	Ida M. Elliot
Owen Bryant	J. P. Jensen
Harrison G. Dyar	H. A. J. McElhose

Evelyn G. Mitchell

The names of fifteen members were dropped from the rolls by the Secretary for the non-payment of dues.

The following were elected to membership by the Executive Committee at its meeting on Wednesday:—

Gal. G, Annals.	H. G. Champion
Edward A. Agar	Royal N. Chapman
Gertrude A. Bacon	H. D. Chase
John W. Bailey	R. N. Chrystal
J. Percy Baumberger	C. P. Clausen
G. E. Bensel	C. J. Cole
A. G. Boving	Nicholas E. Crosby
B. L. Boyden	S. S. Crossman
Henry W. Brolemann	Edward M. Dadd
Alfred E. Cameron	Andrew A. Dalglish
Seth Bunker Capp	C. A. Dawson
Henry F. Carter	George O. Day

Joseph J. De Gryse
D. M. DeLong
Johannes Dewitz
Paul Dognin
Walter E. Dove
A. B. Duckett
John E. Dudley, Jr
E. H. Dusham
John Eckert
J. M. Enburg
Robert Etheridge
J. C. Evenden
G. F. Ferris
Theodore Frison
Angel Gallardo
Gerson Garb
Gustave Gilson
Murray O. Glenn
Emol August Goeldi
Guido Grandi
Charles T. Green
Percy H. Grimshaw
Charles J. Grist
J. E. Gutberlet
V. R. Haber
Henry Hacker
H. R. Hagan
J. E. Hallinen
C. C. Hamilton
C. W. Hauck
Frank B. Herbert
Alfred Hetschko
A. H. Hollinger
Neale F. Howard
W. George Howes
William S. Huntington
Georg Jacobson
F. P. Keen
C. H. Kennedy
Harold H. King
Francis Klapelek
Anton Krausse
E. W. Laake
H. K. Laramore
W. H. Larrimer
David T. Larsen
Cyril E. Latour
H. S. Leigh
Frank M. Littler
T. P. Lucas
W. L. McAtee
Simon Marcovitch
Eva Grace Miller
A. A. C. de Carvalho Monteiro
Martin E. Mosely
John C. Moulton
Roe Niver
Charles Oberthur
Joseph Oizam
Mary H. Oliver
Francis H. O'Neill
Charles J. Pierson
J. J. Pillsbury
Carlos E. Porter
H. A. Preston
C. A. Reese
H. J. Reinhard
S. G. Rich
C. H. Richardson, Jr
Frederick Ris
H. A. Ritchie
Kurt Baron von Rosen
Arthur H. Rosenfeld
Nai Nab Salakshana
Rene Vitalis de Salvaza
H. E. Schradieck
P. W. A. Scott
F. Hazelton Smith
Loren B. Smith
Roger C. Smith
G. J. Spencer
Frederic V. Theobald
Pedro Torgansen
Ivar Tragardh
Juan Tremoleras
Major J. B. G. Tulloch
Conte Emilo Turati
A. Jefferis Turner
Chester F. Turner
B. C. S. Warren
D. B. Whelan
William H. White
C. B. Williams
R. C. Williams
P. B. Wiltberger
William B. Wood
M. P. Zappe.

TREASURER'S REPORT.

RECEIPTS.

Cash on deposit in the First National Bank, Champaign, Illinois, December 8, 1913		$ 132.44
Life Membership Fees deposited with Cleveland Trust Company, Cleveland, Ohio, July 1, 1914		150.00
Interest on Fees of Life Members, July 1, 1914		10.07
Cash received from Herbert Osborn, Managing Editor of the Annals		564.00
Cash collected as Dues		915.99
Checks returned and refused payment, money order not negotiable, and subscriptions		12.00
		$ 1,784.50

BALANCE.

Bills paid, Annals:		
Annals and Separates, June, 1913	$ 270.75	
Annals and Separates, September, 1913	319.60	
Annals and Separates, December, 1913	202.95	
Annals and Separates, March, 1914	226.40	
Annals and Separates, June, 1914	129.25	
Annals, Postage and Expressage	39.33	
Annals, Engravings	61.21	
		$ 1,249.49
Bills paid, Secretary-Treasurer's Office:		
Stamps and Stamped Envelopes	$ 61.86	
Printing and Supplies	95.81	
Printing 1,000 Booklets	16.60	
Stenographer and Office Help	41.35	
Writing Certificates for 1913 and 1914	8.65	
Telegrams	2.21	
		$ 226.48
Checks returned and refused payment, money order not negotiable, and subscriptions		$ 12.00
Life Membership Fees deposited with Cleveland Trust Company, Cleveland, Ohio, December 1, 1914, at 4%		150.00
Interest on Fees of Life Members deposited with Cleveland Trust Company, December 1, 1914, at 4%		10.07
Cash on Deposit in the First National Bank of Champaign, Illinois, December 14, 1914		136.46
		$ 1,784.50

The names of the following Fellows were recommended to the Executive Committee at the Atlanta meeting for election as Honorary Fellows:—

Charles James Stewart Bethune — John Henry Comstock
Charles Henry Fernald — Eugene Amandus Schwarz.

This recommendation was adopted by the Executive Committee and in accordance with the Constitution was referred to the Fellows for a mail ballot. This ballot was taken during the past year and the Executive Committee now declares them duly elected.

The Managing Editor of the Annals of the Entomological Society of America submitted to the Executive Committee the following report for the year ending December 1st., 1914:—

REPORT OF THE MANAGING EDITOR OF THE ANNALS.

The 1914 volume of the Annals has been issued with some delays which have been due in part to the absence of the Editor from Columbus during several weeks of the summer and in part from the uncertainty of the amount available for publication. The volume as completed will contain nearly 400 pages and 45 plates, two of them in color. The numbers have been larger and more profusely illustrated than would have been possible without the contributions of some of the authors. The paper by Professor Triggerson was printed with assistance of a contribution from the author, Professor Gillette of the Colorado Agricultural Experiment Station provided the colored plates accompanying the paper of Miss Palmer, and Messrs. Childs, Severin and McGregor have assisted in the cost of plates for their articles.

The collections for the year have amounted to $593.69. $29.68 has been spent on office account and $564.01 has been turned over to the Treasurer. The income may be classified as follows:—

Subscription Account	$233.06
Sale of Back Numbers	133.61
Reprints	129.02
Special Contributions	98.00
	$593.69

While the Editor would have preferred a somewhat larger volume it did not seem practicable with the income at hand and with a considerable deficit from preceding years to involve the Society in any large amount. With the income of the year it has been possible to bring up payments on the back numbers so that the Society is now in fairly good shape and it seems probable that we can maintain a volume of approximately 400 pages per year.

It is very possible that some of our foreign subscriptions may lapse and that there will be few additional sales on the foreign account during the next year. This may reduce our income slightly. On the other hand a considerable addition to the membership list is reported by the Secretary.

Respectfully submitted,

HERBERT OSBORN.

In accordance with Article VII of the Constitution, adopted at the Atlanta meeting, that the Editorial Board of the Annals shall consist of ten members, one of whom shall be the Managing Editor and the other members of the Board shall serve for three years, three members retiring annually, the Executive Committee took the following action. Professor H. C. Fall was elected as the additional member of the Board and the following dates fixed as the time for the retirement of the different members: J. H. Comstock, C. J. S. Bethune and C. W. Johnson to retire in 1915; V. L. Kellogg, L. O. Howard and W. M. Wheeler to retire in 1916; P. P. Calvert, J. W. Folsom and H. C. Fall to retire in 1917.

The following members were elected as Fellows:—

Nathan Banks	A. P. Morse
J. Chester Bradley	P. J. Parrott
W. E. Britton	Edith M. Patch
C. T. Brues	A. L. Quaintance
H. T. Fernald	J. A. G. Rehn
Glenn W. Herrick	W. A. Riley
J. S. Hine	Annie Trumbull Slosson
O. A. Johannsen	E. M. Walker
A. L. Melander	H. F. Wickham

E. B. Williamson.

The membership of the Society as reported at the Atlanta meeting consisted of one Honorary Fellow, 36 Fellows, and 402 Members. There is reported at this meeting the election of 12 Members on June 1st, the death of one Fellow and two members during the year, the resignation of one Fellow and six Members at this meeting, the dropping from the rolls of the names of fourteen Members for the non-payment of dues, and the election of 120 Members at this Meeting. The present enrollment of the Society consists of 5 Honorary Fellows, 48 Fellows, and 498 Members, or a total of 551.

The Committee consisting of Mr. Nathan Banks and Mr. Morgan Hebard, of which the late Mr. H. H. Lyman was also a member, appointed at the Atlanta meeting to report at this meeting on the feasibility of establishing a Thomas Say Society, presented the following report to the Executive Committee:

THOMAS SAY FOUNDATION.

The Committee on the Thomas Say Society report as follows: They find there is an increasing demand for the means of publication of larger works on American systematic entomology, and they therefore recommend to the Entomological Society of America the following plan for the issuance of such works under the title of "The Thomas Say Foundation."

To accomplish this purpose the Society shall appoint a temporary committee of five members who shall have charge of all matters concerning the Foundation until more definite plans are adopted by the Society.

This Committee shall consist of an Editor, a Treasurer, and three other members, all of whom shall be appointed by the Executive Committee of the Society. They shall be authorized to solicit, hold, and spend subscriptions and funds for the purpose of obtaining a permanent fund for this Foundation and for the issuance of such works on American Systematic entomology as the Committee shall deem worthy of publication.

They shall also be empowered to determine the form, character, price and other details of the publication. The Treasurer of the Entomological Society of America be authorized to pay bills not to exceed fifty dollars for the preliminary expenses of presenting this matter to the entomological public.

This Committee is charged with making a report of their operations and expenditures to the Executive Committee of the Society at its next Annual Meeting.

To put this plan into definite shape the Committee would suggest the following amendment to the Constitution of the Entomological Society of America, which shall be known as Article VIII of said Constitution:

ARTICLE VIII.

SECTION 1. NAME—This fund, the publication, and the committee shall be known as "The Thomas Say Foundation."

SECTION 2. PURPOSE—The purpose of this Foundation is for the publication of works of a monographic or bibliographic character on the insects of North America.

SECTION 3. PUBLICATION—Each publication shall be a volume complete in itself, and numbered consecutively.

SECTION 4. COMMITTEE—This Committee shall consist of six members, four of them to be elected by the Executive Committee of the Society, two retiring annually, and an Editor and a Treasurer to be designated by the Executive Committee.

SECTION 5. POWERS—This Committee is empowered to determine all matters concerning the publication.

SECTION 6. FUNDS—They are also empowered to solicit, hold, invest, and expend funds committed to their care; only the interest from any endowment fund to be available.

SECTION 7. RESPONSIBILITY—The Society shall be in no way responsible for debts contracted by this Foundation, unless previously authorized by the Executive Committee.

SECTION 8. REPORTS—The Editor and Treasurer shall present a report of their operations and expenditures to the Executive Committee at each Annual Meeting, and the accounts of the Treasurer shall be audited by the Auditing Committee of the Society. These reports shall be published as a part of the proceedings of the Executive Committee of each Annual Meeting.

MORGAN HEBARD,
NATHAN BANKS.

The report was adopted by the Executive Committee and the following persons were named as the temporary committee for the Thomas Say Foundation: J. M. Aldrich, Nathan Banks, Morgan Hebard, Alex. D. MacGillivray and E. P. Van Duzee. The Executive Committee empowered this temporary committee to select its own officers.

[The four members of the temporary committee in attendance at the Convocation Week meetings held a meeting at the Academy of Natural Sciences and discussed ways and means of publication and elected Morgan Hebard as Treasurer and Alex. D. MacGillivray as Editor.]

The Executive Committee directed the Secretary to prepare for publication with the proceedings of the Philadelphia meeting, the Constitution, a list of officers, and a list of members.

There have come to the Secretary some reports of the non-receipt of the Certificates of Membership furnished by the Society. The Secretary has mailed a certificate to all those entitled to receive them for each year except the present. He still has some certificates for each year except 1910 and would be glad to supply those who have not received one, as long as the supply lasts.

In order that the Summer Meeting to be held on the Pacific Coast in 1915, may be properly looked after, the Executive Committee recommends the election of Dr. E. C. Van Dyke of the University of California, as Local Secretary. It shall be his duty to arrange the program, act as Secretary for the meetings, and prepare the report of the proceedings of the meetings for publication in the Annals.

Dr. C. Gordon Hewitt moved the adoption of the Report of the Secretary–Treasurer and that the motion should include an expression of the Society's deep appreciation of the efforts of the Secretary-Treasurer during the last year in the direction of increasing the membership and scope of the Society, which efforts had been so eminently successful. Motion adopted.

COMMITTEE ON RESOLUTIONS.

Yours committee on resolutions beg to submit the following:—

Resolved, that the thanks of this Society are due, and are hereby tendered to the University of Pennsylvania, the Academy of Natural Sciences, and the local Committee of the American Association for the Advancement of Science in providing for the comforts and pleasures of our members which have added so much to the success and profit of the Society while in this city.

Resolved, that the thanks of the Society be further tendered to the American Entomological Society, the Feldman Collecting Social and other entomologists for their courtesies and entertainment; also to the local press for exceptional courteous treatment, to the local officers for their extremely successful efforts in providing for the expeditious dispatch of the business of the Society, all of which have contributed to make the Philadelphia meeting one of the most successful in the history of the Society.

(Signed) F. M. WEBSTER,
HENRY BIRD,
J. S. HOUSER.

REPORT OF THE COMMITTEE ON NOMINATIONS.

Your committee begs leave to report the following names as nominees for the various offices for 1915:—

OFFICERS.

President: Vernon Lyman Kellogg, Leland Stanford Junior University, Stanford University, California.

First Vice-President: J. S. Hine, Ohio State University, Columbus, Ohio.

Second Vice-President: J. M. Aldrich, U. S. Bureau of Entomology, Lafayette, Indiana.

Secretary-Treasurer: Alex. D. MacGillivray, University of Illinois, Urbana, Ill.

ADDITIONAL MEMBERS OF THE EXECUTIVE COMMITTEE.

C. T. Brues, Harvard University, Bussey Institution, Forest Hills, Boston, Mass.

W. A. Riley, Cornell, University, Ithaca, N. Y.

E. C. Van Dyke, University of California, Berkeley, Calif.

T. D. A. Cockerell, University of Colorado, Boulder, Colorado.

J. A. G. Rehn, Academy of Natural Sciences, Philadelphia, Pa.

MEMBER OF COMMITTEE ON NOMENCLATURE.

Nathan Banks, U. S. Bureau of Entomology, East Falls Church, Virginia.

(Signed) J. CHESTER BRADLEY,
C. P. GILLETTE,
J. A. NELSON.

On motion, the Secretary was instructed to cast a ballot for the officers named and they were declared elected.

It was later pointed out by a member of the Committee on Nominations that Dr. E. C. Van Dyke, not being a Fellow, was not eligible to election to the Executive Committee. On motion, the Society declared his place vacant and instructed the Executive Committee to fill the vacancy.

(The Secretary has taken a mail ballot of the Executive Committee and Professor A. L. Melander, Washington Agricultural College, Pullman, Washington was elected to the vacant place.)

REPORT OF THE AUDITING COMMITTEE.

December 31st, 1914.

We, the undersigned, have this day examined the accounts of Alexander D. MacGillivray, Treasurer and Secretary of the Entomological Society of America, for the year ending December 14th, 1914, and the accounts of Herbert Osborn, Managing Editor of the Annals of the Entomological Society of America for the year ending December 1st, 1914, compared the vouchers therewith and found them correct and properly cast.

(Signed) WM. T. DAVIS,
J. H. EMERTON,
FRANK MORTON JONES.

REPORT OF THE SPECIAL COMMITTEE ON THE SUMMER MEETING OF 1915.

The committee reports in favor of holding a meeting on the Pacific coast in conjunction with the zoological section of the American Association for the Advancement of Science, the precise dates to be selected by a local committee, the latter to be appointed by the President and authorized to complete the arrangements respecting the program, meeting places, hotel headquarters and other matters essential to a successful gathering.

We recommend that this meeting be as much in the nature of a congress as possible, in order that certain outside entomologists, including a number of foreigners who are expected to be present, may present papers and take part in the discussions. The desirability of presenting papers of general interest or of emphasizing the wider applications of special investigations is mentioned in this connection. A number of smaller entomological societies expect to meet at the same time, and this arrangement will therefore admit of a larger and more enthusiastic gathering. The transaction of any business would naturally be restricted to members of the Entomological Society of America.

It is also felt that in making up the program, cognizance should be taken of the dates when certain general sessions of the zoological section of the A. A. A. S. are held.

The committee considers it very desirable to have a hotel headquarters designated, since this greatly facilitates intercourse between visiting entomologists. Several of the committee favor a banquet of some nature and it is presumable that such a feature would appeal strongly to all in attendance.

The committee would also call attention to the summer zoological camp conducted under the auspices of the University of California and located in the Sierras close to Lake Tahoe. This will be open from the middle of June until the end of July, not only to undergraduates and postgraduates who wish to take up field work, but also to

general entomologists who would care to stop off for a week or so and do a little collecting in the high mountains. The site is ideal, being accessible to the main transcontinental railroad and in one of the most beautiful parts of the Sierras. The location was selected with a view to its accessibility to Eastern entomologists.

Attention of entomologists should also be called to the California Fruit Growers' Convention at Stanford, to be held the week immediately preceding the session of the American Association for the Advancement of Science. This gathering should be of much interest to economic entomologists.

We are informed that a special committee of the American Association for the Advancement of Science expects to issue a scientific handbook* for sale at a low price to members of the American Association and affiliated societies. This publication will give a great deal of information concerning the geography, topography, fauna and flora of California, together with data respecting railways, hotels, etc.

All of which is respectively submitted.

(Signed) E. P. FELT, W. M. WHEELER,
V. L. KELLOGG, T. D. A. COCKERELL,
A. J. COOK, E. C. VAN DYKE.

On motion, the report of the Committee was adopted and the Committee discharged.

The following amendment to the Constitution submitted at the Atlanta meeting was read:—

ARTICLE IV, Section 2.—The business of the Society not otherwise provided for shall be in the hands of an Executive Committee, consisting of the officers named in Section 1, and of six additional members, five of whom shall be elected from the Fellows of the Society, and the sixth shall be ex-officio the Managing Editor. Four members of the Committee shall constitute a quorum.

To be amended to read:

ARTICLE IV, Section 2.—Executive Committee. The business of the Society not otherwise provided for shall be in the hands of an Executive Committee, consisting of the officers named in Section 1, and six additional members, five of whom shall be elected from the Fellows of the Society, and the sixth shall be ex-officio the Managing Editor. There shall be a meeting of the Executive Committee at each Annual Meeting. Four members shall constitute a quorum and in the case of the non-attendance of this number at any Annual Meeting, the Society shall elect a sufficient number from among the Fellows in attendance to complete the quorum.

On motion, the amendment was adopted.

*This handbook is issued by Paul Elder & Co., 239 Grant Avenue, San Francisco, Cal., under the title "Nature and Science on the Pacific Coast" at $1.50 net.

The following resolution was moved by Dr. J. Chester Bradley:—

That the Committee on Nomenclature be requested to formulate rules for the preservation and fixation of family names, with a view after approval by the Society to ultimately presenting them to the Nomenclatorial Committee of the International Congress of Entomology.

That the Committee on Nomenclature be requested to prepare a list of a few of the more important names in each order which are in danger of being lost or changed in sense by strict application of the rules of nomenclature, which it is desirable should be preserved, and present this list, after approval by the Society to the International Commission on Nomenclature with the request that the rules be suspended in the case of these names, and their use permanently authorized.

On motion, the resolution was adopted and referred to the Committee on Nomenclature.

The following papers were then presented:—

FREDERICK KNAB, U. S. National Museum.—The Nemocera not a Natural Group of Diptera.

ALVAH PETERSON, University of Illinois.—Studies on the Morphology of the Head and Mouth-parts of Diptera. Read by title.

C. P. GILLETTE, Colorado Agricultural College.—Interpretation of the Codling Moth Data from Colorado.

V. E. SHELFORD, University of Illinois.—Modification of the Color Paterns of *Cicindela* by Temperature and Moisture. Read by title.

NATHAN BANKS, U. S. Bureau of Entomology.—Suggestions for Discovering Affinity and Phylogeny.

C. P. GILLETTE, Colorado Agricultural College.—Insect Notes from Colorado.

A. D. MACGILLIVRAY, University of Illinois.—The Modification of the Subcostal Vein in the Wings of Insects. Read by title.

N. E. MCINDOO, U. S. Bureau of Entomology.—The Olfactory Sense of Coleoptera.

JAMES ZETEK, Entomologist Republic Panama.—The Ecology of Plague. Read by title.

F. M. WEBSTER, U. S. Bureau of Entomology.—Importance of Observations apparently Unimportant. Read by title.

HERBERT OSBORN, Ohio State University.—Life-history Studies on the Cercopidæ and Jassidæ.

C. R. CROSBY, Cornell University.—An Insect Enemy of the Four-lined Leafbug. Read by title.

The exhibition was held in Room 112, Zoological Laboratory under the direction of Dr. Philip P. Calvert. The following exhibits were shown:—

J. H. EMERTON.—Circulating Collection of Spiders.

HERMAN H. BREHME.—Life Histories of Economic and other Insects.

HARRY B. WEISS.—An Improved method of Mounting Insects.

On motion, the Society adjourned to meet in one year with the American Association for the Advancement of Science at Columbus, Ohio.

ALEX. D. MACGILLIVRAY, *Secretary.*